Teacher's Edition

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THE NATURAL WORLD

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THE NATURAL WORLD MODULES/LEVEL 3

PROGRAM DIRECTORS

Ernest Burkman THE FLORIDA STATE UNIVERSITY
Stewart P. Darrow THE FLORIDA STATE UNIVERSITY
David D. Redfield THE FLORIDA STATE UNIVERSITY
William R. Snyder THE FLORIDA STATE UNIVERSITY

SILVER BURDETT COMPANY
Morristown, New Jersey • Glenview, Ill. • Palo Alto • Dallas • Atlanta

PROGRAM CONSULTANTS

Joseph Agresta	COLONIA JUNIOR HIGH SCHOOL, WOODBRIDGE, NEW JERSEY
Thomas Atkinson	STATE UNIVERSITY OF NEW YORK AT ALBANY
Thomas Boehm	STATE UNIVERSITY OF NEW YORK AT ALBANY
Sarah Craig	FLORIDA STATE UNIVERSITY
Francis Chenoweth	SCHROP JUNIOR HIGH SCHOOL, AKRON, OHIO
Richard Daume	PARKWAY EAST JUNIOR HIGH SCHOOL, CREVE COEUR, MISSOURI
Frederick Johnson	SHELBY COUNTY BOARD OF EDUCATION, MEMPHIS, TENNESSEE
Mable Lund	MOUNTAIN VIEW JUNIOR HIGH SCHOOL, BEAVERTON, OREGON
Joan Powell	EAST JUNIOR HIGH SCHOOL, WEST CHESTER, PENNSYLVANIA
Charles Richardson	BELZER JUNIOR HIGH SCHOOL, INDIANAPOLIS, INDIANA
Clarence Trentlage	FREEDOM HIGH SCHOOL, FREEDOM, WISCONSIN

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Introduction

These modules are quite unlike most materials used in science courses. The content, the approach, and the underlying objectives probably stand in sharp contrast to those in the books you are accustomed to.

This Teacher's Edition has been designed to help you help your students as they study this module. Parts A and B give a brief overview of the module and its objectives. Parts C and D provide some detailed information about equipment, local supply items, and safety. Marginal notes in the chapters identify key questions, alert you to materials that must be prepared in advance, and suggest how to handle certain trouble spots. You may wish to add notes of your own as you work with this module.

The authors suggest that you read "A Brief Talk," in the introductory section of the student portion of each module, before you begin using the modules in your teaching. And of course you'll want to make regular use of the Instructional Management Guide. It has all kinds of suggestions for making the best use of the modules, the Record Books, and the Resource Book.

PART A • OVERVIEW

The activities in this module are an introduction to the nature of the sun in our solar system. These activities focus on the methods scientists have used to find answers to questions they have asked about the sun and the solar system. How one determines astronomical distances, calculates energy release from the sun, and judges the composition of that star give rise to an understanding of how our solar system works. This module emphasizes the logic and the processes of science more than the usual descriptive facts of astronomy.

Chapter 1 introduces the intent of the module via five questions. Finding answers to these questions is the task of the students as they work not only in this chapter, but also in the chapters that follow. The chemical composition of the sun is first in importance. Spectroscopic analysis is the tool presented. Students use a simple spectroscope to do some qualitative detective work. Line spectra from flaming chemicals are shown to be characteristic of the specific chemical present. Thus it is shown that similar techniques can be used to determine the substances present in stars.

Chapter 2 begins to answer the question, How much energy does the sun give off? Students are required to construct an energy measurer. They make a pyrheliometer—a heat detector that responds to light. With this device, temperature change due to varying light conditions can be roughly measured. The effect on the pyrheliometer of known light sources with different amounts of energy is determined. The argument is then presented that the sun's effect can be compared with that of a source of known energy. But another variable must be considered—the distances from the pyrheliometer to the energy sources.

Excursion 2-1 reviews certain basic notions about energy: how it can be transferred and changed from one form to another. This is backup information for the content of Chapter 2.

Chapter 3 develops the idea that the amount of energy received by the pyrheliometer (called the sun-energy measurer) is a function of the distance to the light source. The activity shows that increasing distance to the light source rapidly decreases the energy measured by the pyrheliometer. In fact, the data collected, when graphed, show an inverse square relationship. The effect of sunlight is compared with that of a 150-watt bulb, and is shown to be far greater. How much greater depends on the distance to the sun, and therein lies another set of problems.

Chapter 4 presents the beginning step in finding the distance to the sun, the method of triangulation. A range finder is introduced and found to be inadequate because of its short base line. But the technique suggests that if a longer base line were available, the distance to the sun could be deter-

mined. The success of the longer base line is illustrated for measuring the distance to the moon.

Excursion 4-1 introduces a simple but fairly precise method for measuring the diameter of the moon, based on direct observation of its motion.

Chapter 5 uses a simple model of three elements of the solar system (Sun, Earth, and Venus) to provide an adequate base line for measuring the distance to the sun. The model requires the application of certain facts regarding the motion of the two planets relative to each other and to the sun, and the scale drawing of how these bodies relate to each other. This indirect method provides a reasonably accurate measurement of the distance from the earth to the sun.

Excursion 5-1 defines the term *radar* and describes how radar is used to measure certain astronomical distances, e.g., the distance to Venus. It also explains why radar is not used to obtain an accurate measurement of the distance to the sun.

Excursion 5-2 illustrates the use of scale drawings.

Excursion 5-3 shows a direct application of scale drawings in using the Earth-Sun-Venus model.

Chapter 6 provides an indirect approach to the measurement of the sun's diameter, another dimension needed to finally judge the total energy output of the sun. A pinhole sighting scope is used to project the diameter of a light source of known distance. A mathematical relationship is presented that can be employed to determine the diameter of the sun, given the size of its image as projected by the sighting scope.

Excursion 6-1 presents some history on the development of the telescope and how the laws of optics act in projecting and transforming images. Several activities give firsthand evidence of how lenses and telescopes work.

Chapter 7 focuses on the relative motions of the earth and sun. It illustrates why observations of these two bodies alone do not provide conclusive evidence for either a sun-centered or an earth-centered solar system. Other kinds of observations are necessary to resolve the controversy, and logic must also be used.

Excursion 7-1 reviews historically the development of various calendars.

Excursion 7-2 gives students an opportunity to analyze astronomical data and decide which of two ancient theories of the solar system best explain the data.

Chapter 8 reviews the key questions presented in Chapter 1. Only one of the questions remains still partially unanswered: How can you find out how much energy the sun gives off? A final comparison of light sources and a long-hand version of the inverse square law yield the answer. The rest of the chapter asks the student to apply what has been learned in analyzing the characteristics of two hypothetical stars. Data for each star are provided and the student is asked to compare their chemical composition, their distances, and their energy output.

Excursion 8-1 presents the concept of power as the rate of energy transfer. It also defines the watt.

PART B • MODULE OBJECTIVES

Chapter 1

- Describes what a spectroscope does to reflected sunlight.
- Describes the difference between continuous and bright-line spectra.
- Recalls the characteristics of the spectrum of sodium when burned and identifies it as bright-line.
- Distinguishes between a continuous and a bright-line spectrum.
- Explains the safe use of a spectroscope.
- Matches different light sources with their spectral types.
- Describes the difference between bright-line and dark-line spectra.
- Applies method for identifying chemicals by using a spectroscope.
- Applies the concept that spectral data can be used to identify chemical elements of light sources.

Chapter 2

- Indicates that light and heat are forms of energy and that light can be converted into heat.
- Explains the blackening of the vanes of the sun-energy measurer.
- Accurately reads the change in temperature, using a Celsius thermometer scale.
- Lists the variables that affect an object's temperature change.
- Uses the sun-energy measurer to measure temperature change due to light source.
- Selects graph showing that a sunlit object's temperature reaches and maintains a maximum in a finite time span.
- Explains why only one variable is changed at a time.
- Identifies relative energy output of bulbs of different wattage.
- Applies the concept that temperature change is directly related to energy output of light source.

Chapter 3

- Calculates temperature change.
- Selects ordered pairs and constructs a graph.
- Extrapolates from graphed data.
- Applies relationship of inverse effect of distance from energy source on temperature change of sun-energy measurer.

Chapter 4

- Identifies parts and characteristics of a range finder.
- Explains scale markings on a range finder and how they can be varied.
- States the relationship of distance and sighting angle.
- Identifies factors that limit the use of a range finder.
- Demonstrates skill in measuring distance by using a range finder.
- Identifies the base line for astronomical sightings.
- Explains why the range finder cannot be used to measure the distance to the sun.

Chapter 5

- Identifies basic facts about the solar system.
- Uses a protractor to measure angles.

- Interprets scale drawings.
- Identifies and measures the greatest earth-planet, earth-sun angle from a drawing.
- Prepares and uses a scale model of planet orbits to determine scale and actual distances between planets and distance from the earth to the sun.

Chapter 6

- Describes relationship of object and image size and distance to pinhole.
- Demonstrates safe and accurate use of sighting scope.
- Applies relationship of object and image size and distance to pinhole to calculate diameter of the moon.
- Applies relationship of image, object size, and distance to pinhole in determining distance to the object.

Chapter 7

- Describes the earth's rotation in terms of degrees.
- Identifies length of time from noon to sunset.
- Applies the concept that each hour represents 360/24 degrees of rotation.
- Applies the concept that there is one time zone for every hour in a 24-hour day.
- Recalls that observations of the sun's motion can result in conclusions of both a sun-centered system and an earth-centered system.
- Indicates cause of a shadow's appearance and position, due to position of light source and object casting shadow.
- Explains why it is more logical to think the solar system is sun-centered.

Chapter 8

- Applies concept of how energy received from light source diminishes with distance.
- Applies concept of inverse square relationship.
- Defines *power*.
- Applies the concept that the power multiplier is the square of the distance multiplier.
- Compares characteristics of stars, given spectral and energy data.
- Designs an experiment applying concept of energy measurement.

PART C • SPECIAL EQUIPMENT AND MATERIALS

Advance Preparations

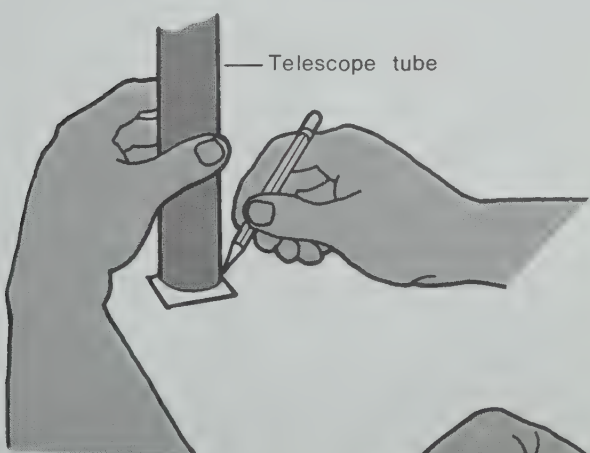
The sighting scope used in Chapter 6 must be prepared in advance of the time it will be needed. The basic kit for this instrument is the telescope tube package. For each sighting scope you will need:

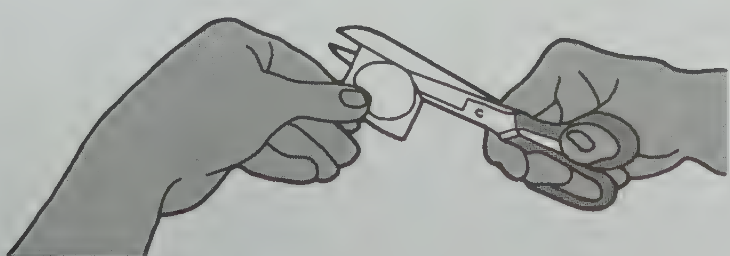
1 telescope tube package
1 piece of thin cardboard (tablet back)
1 piece of frosted acetate, 4 cm^2

To complete the assembly of the sighting scope you will also need these materials:

Sharp pencil
Scissors
Razor blade
Large needle or pin

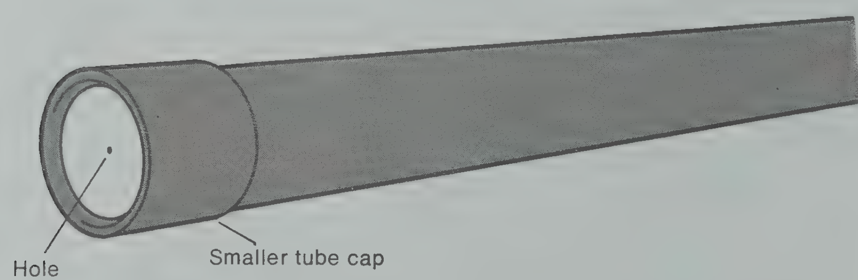
Step 1. Remove the *smaller* cap from the telescope tube. Trace the outside of the tube (not the cap) on the thin cardboard. Then cut out the disk.



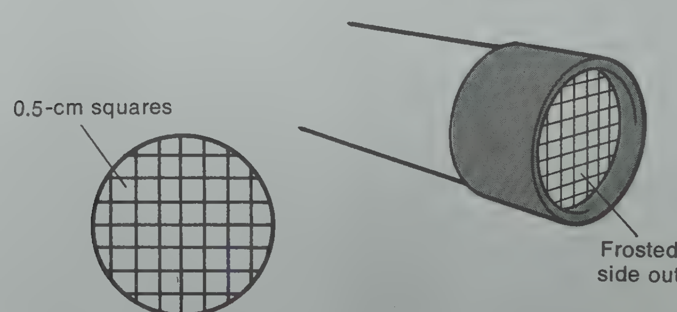


Step 2. Make a smooth pinhole in the center of the cardboard disk. Don't make the hole too large. The maximum size should be no more than 1 mm.

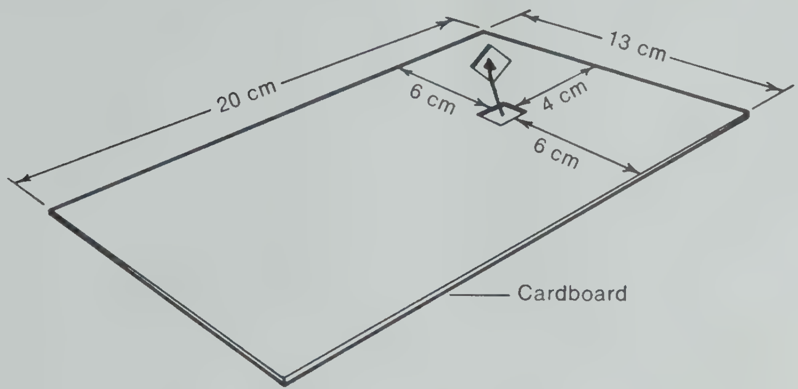
Place the disk inside the tube cap and replace the cap on the tube.



Step 3. Now prepare an acetate disk to fit the *larger* tube cap. Use a well-sharpened pencil to mark off 0.5-cm squares on the frosted side of the acetate disk. This must be accurately done. Place the disk in the tube cap, frosted side out. Replace the cap on the tube.



Step 4. You should prepare a light-intensity board to go with each sighting scope. Mark off a 1-cm square on a 13 cm × 20 cm cardboard sheet in the position shown. Use a razor blade to cut the square from the cardboard sheet.



Local Supply List
Cardboard tablet backs
Distilled water
String
Matches
Paper towels
Scissors
Razor blade
Small bottles, with stoppers or lids
Paper clips
Colored map pins
Tissue
Modeling clay
Straight pins
Hat pin or large needle

PART D • SAFETY NOTES

In Chapter 1, students work with alcohol burners. They should be cautioned regarding fire safety and instructed in the safe use and storage of the burners. Alert students to the following safe-use rules.

- Never fill a burner more than half full with alcohol.
- Do not light a burner from another burner.

- Be sure the flame is extinguished and the wick is cool to the touch before returning a burner to the supply area.
- Always replace the metal cap over the wick before returning a burner to the supply area.
- Tie back hair that extends below the ear lobes, or use a hair net.
- Always wear safety goggles when using a burner.

The nichrome wire used in the spectroscope flame tests gets hot if it is held in the flame too long. You may want to wrap the unlooped end of the wire with tape, or secure it to the side of a short piece of dowel.

If you advise students to use hydrochloric acid ($HC1$) to clean the nichrome wire, be sure they are instructed in its safe use. Hydrochloric acid fumes are noxious. It would be best if you cleaned the nichrome wires yourself, in a well-ventilated area.

Caution your students never to look directly at the sun when using the spectroscope. The same caution applies in Chapter 6 when the sighting scope is used to get an image of the sun on the acetate screen.

Before beginning this module, it would be good to have your students view the filmstrip *Laboratory Safety,* developed by EdMediaTec and distributed by Silver Burdett.

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Contents

A Brief Talk

There are many ways to study science. No single way is the best for everybody. We've prepared this book, and others, to introduce you to science a bit at a time. We could have written a long book with many ideas and many chapters. Instead, we chose to present a few important things for you to think about in each of these books. And we've done it in such a way that you can *do* science activities—not just read about them.

To do science activities, you need equipment and materials. So we have asked that these be gathered together right in your classroom. Look around; you'll probably see some of them.

Getting What You Want

Each book like this one has a purpose. The title will give you some idea of what's inside. But to get a better idea of what's there, thumb through the pages. See what activities you'll be doing and the kind of equipment you'll be using.

First, you'll have a say in choosing the modules you want to study. Second, you can choose to do, or not to do, some of the activities within each module. These activities are called Excursions. Third, you can get help with your own special problems by doing other short activities. These activities are called Resources. You'll find them in the *Resource Book.*

Fourth, you can check up on your own progress, Self-Evaluations are provided for each module chapter. You'll find them in the *Record Book.* And you'll find their answers there, too.

Working on Your Own

Your science class may be quite different from your other classes. This book, and others like it, will guide your study of science. Your teacher will not direct all your work. You'll be responsible for your progress. You'll also be responsible for taking good care of equipment and materials.

Begin each day's work where you left off the time before. Try to work ahead on your own or with your partner, if you have one. If you meet problems you can't solve, get help. But don't expect your teacher to give you the answers to the questions in the book.

After a few days, some of your classmates who are using this module may be ahead of you. Others may be behind. And other students will be studying different modules. This is how the course is supposed to work. No prizes will be given for being the first to finish a module. Work at a pace that is best for you. But be sure you understand what you have done before moving ahead.

Problem Breaks

Problem Breaks in modules give you a chance to be your own boss as you investigate. Some information and guidance are provided in each one. But you'll have to do the planning yourself. You'll often be expected to report your findings to your teacher and/or your classmates. Problem Breaks are important and should not be skipped. They aren't designed as just something else to do. They are central to what you are expected to learn in each module in which they appear. Their most important purpose is to help you learn how to think through a problem and design a method for solving it. The following comments may help you get the most out of doing Problem Breaks.

- Read the entire Problem Break carefully a couple of times before you do anything else. This will help you see how it fits in with what you've been doing. And it will tell you what you need and whether you should work with a partner. If you do work with a partner, do your planning together.
- Have the teacher check your plan of action before you start if the Problem Break includes an experiment to design. This can save you time and embarrassment. And it will ensure that what you want to do is safe for the classroom and doesn't demand too much equipment.

- Don't rush to get through a Problem Break. Most Problem Breaks are designed for one class period. But you may discover something on your own that you want to keep after for a while. That's fine. Talk it over with your teacher. Chances are you can keep on working as long as you want.
- Keep good records of what you do, observe, and conclude. Often you'll have to construct your own data tables, graphs, and maybe even equipment. Good records will be essential if you have to describe your work to others.
- Don't expect your teacher to have all the answers to the problems and questions in Problem Breaks. Most Problem Breaks are not designed to result in one answer to a question. How you go about your work will often determine the results you get. Other persons may get different results because they will probably choose a different plan of attack. And that is just the way it should be. Problem Breaks give everyone a chance to operate independently.

You can see that Problem Breaks are an essential part of the module design. Therefore, you can expect to see a question or two about each one in the Self-Evaluation section of the chapter in which it appears.

Safety in the Laboratory

This module will allow you to do several experiments. If you do them properly, they are perfectly safe. There are instructions and drawings to help you do each of the activities. But you should also observe the following rules:

- Equipment and chemicals should be used only in the classroom, unless your teacher gives you permission to use them elsewhere.
- Your work area should be left clean. Clean all equipment after use and return it to the supply area.
- Handle all chemicals carefully. Keep them away from your eyes, ears, nose, mouth, clothing, and skin.
- Read labels. Use chemicals only from containers that are clearly labeled.
- Wipe up spills with damp paper towels.
- Report any accidents immediately to your teacher.
- Throw waste materials into the proper containers.
- Wash your hands at the end of each laboratory period.
- Goggles should be worn when you are working with chemicals, when you are heating materials in test tubes, or when you could be harmed by flying objects.

What You Are Expected to Learn

During the year, you will work much as a scientist does. You should learn some useful information. More important, we hope that you will learn how to ask and answer questions about nature. Keep in mind that learning how to find answers to questions is just as valuable as learning the answers themselves—maybe even more valuable.

Do not write in this book unless it belongs to you. Do all your writing in your *Record Book*. Use your *Record Book* to check your progress with the Self-Evaluations.

From time to time, you will find that your answers to questions aren't the same as those of your classmates. Don't let that worry you. There are several right answers to some questions. And some questions may not have a correct answer. This may disappoint you at first. But soon you'll realize that there is much in science that isn't yet understood. So in this course, you will learn some things we don't know as well as some of the things we do know.

The Message of Sunlight

1

CHAPTER EMPHASIS

The basic theme of this unit is understanding that indirect methods of measurement and observation are used to study the stars and planets.

The student is introduced to the use of the spectroscope and the ways in which it aids in making inferences about the composition of light sources.

FILMSTRIP KEY

Analyzing a Spectrum

EQUIPMENT LIST

Per student-team

1 spectroscope
1 sheet of white paper
2 pegboard backs
3 alcohol burners
1 medicine dropper
3 petri dishes
3 10-cm lengths of nichrome wire
3 3-cm lengths of masking tape
1 glass or baby-food jar
2 10-cm lengths of string

Per class

1 incandescent light source (150-watt bulb in receptacle)
1 fluorescent light source
Distilled water
Strontium chloride
Sodium chloride
Lithium chloride
Methanol (for burners)
Matches
Scissors
Crayons or colored pencils (optional)
3 petri dishes (for "unknowns")
3 10-cm lengths of nichrome wire

MAJOR POINTS

1. A spectroscope spreads light into its component colors.
2. A diffraction grating is the part of the spectroscope that spreads the light.
3. Sunlight and incandescent bulbs form a continuous spectrum.
4. A fluorescent lamp forms a continuous spectrum with bright lines on it.
5. Different elements, when heated to incandescence, show specific bright lines of color.
6. Bright lines of particular colors in the spectrum can be used to predict the presence of definite elements in a substance.
7. The presence of helium was first suspected by the specific lines formed in the sun's spectrum.

Space probes have photographed Mars and the moon. The Mariner space probes actually sampled the atmosphere of Mars. Men have walked on the moon's surface. They have brought back rock samples and detailed photographs. Surprisingly, these developments have led to few unexpected results. Most of the information collected supported what astronomers already believed.

How did astronomers get such accurate information about stars, the moon, and planets without actually going to them? How do you study stars and planets without touching them? Or even without seeing them? These are questions you will tackle in this module.

Your life depends on one star, the sun. That's a good place to start your study of astronomy. To begin, see if you can answer questions 1-1 through 1-5. If you can't, don't worry. You'll get another chance in Chapter 8.

☐ **1-1.** How do astronomers know what the sun is made of?

☐ **1-2.** How can you find out how much energy the sun gives off each minute?

☐ **1-3.** How can the distance to the sun be determined?

☐ **1-4.** How can the size of the sun be determined?

☐ **1-5.** How can the motion of the sun be described?

Note that each question asks "how" information is obtained and "how" measurements are made. Its the "how it's done" that you'll study. Finding out "how" will call for more thought than memorizing facts from a book.

GETTING STARTED

Let's get started on your first "how" question, question 1-1. Although you may not realize it, the sun is constantly sending you information about itself. Unfortunately, you can't read the information like a newspaper. The information is in the form of light. What light tells you about the sun is like cracking a code.

Here is one of the ways to "read" sunlight. Observe how it behaves when it passes through certain materials. You've probably seen an example of this after a rainstorm. Light passes through droplets of rain. At a certain angle it is broken up into a series of colors. Most people call this a rainbow. Scientists call it a *spectrum*.

On the next page, students begin using the spectroscopes. You will probably want to have them assembled, with the gratings and slits in place. This will avoid the danger of students getting fingerprints on the plastic gratings during assembly. Fingerprints tend to cut down the efficiency of the spectroscope. Warn students against touching the plastic, before they begin using it. Gratings can be cleaned with methanol (burner alcohol) and a soft cloth or cotton. Do not scrub. Extra gratings are supplied in the kit, and in the event that cleaning will not suffice, you will have to install a new grating. A student who cannot distinguish colors will be at a disadvantage. If you have students who are color-blind, team them up with ones who are not. But be sure that it is not just a case of looking for the spectrum in an incorrect manner. The student may only need a little additional help in using the spectroscope.

Although it is not necessary for the student to know, the rainbow is produced in a somewhat different manner than the spectrum from a diffraction grating. In a rainbow, the differential bending of the colors of light as they pass from one medium to another (water droplets to air) in a process called refraction forms the color spectrum. In the grating, light is diffracted—spread out—as it passes through thousands of tiny slits, and a color spectrum is formed.

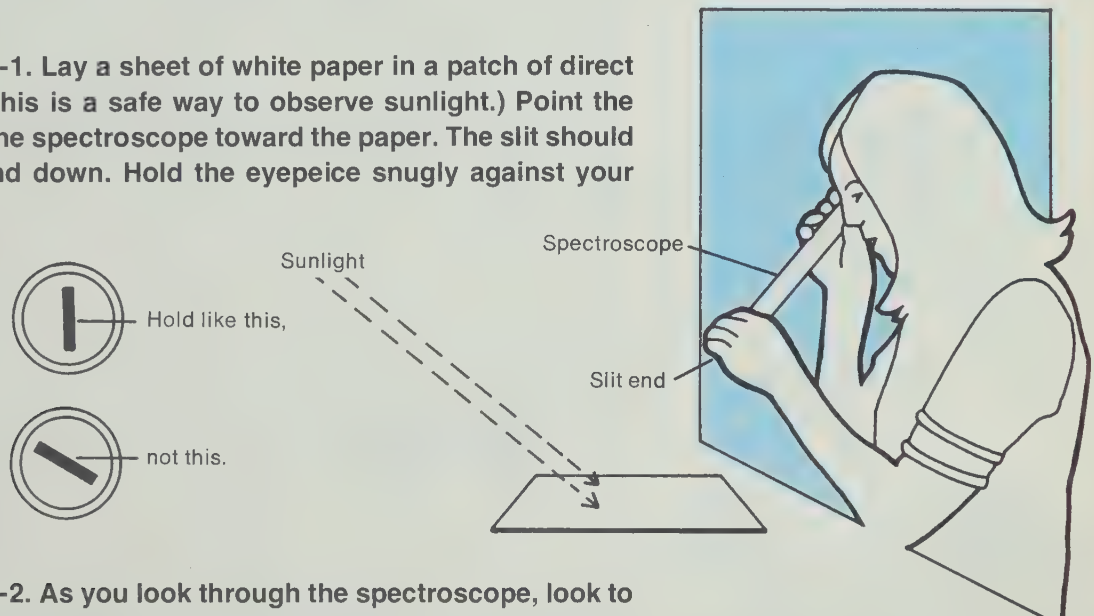
To see and study the sun's spectrum, you will use a device called a *spectroscope*. Before you start, however, here is an important warning.

Students may notice a second spectrum farther out on both sides. This may tend to confuse them. Actually it is spread out wider and is much dimmer than the primary spectrum, but all the colors are in the same order. The fact that it is spread out wider tends to make the separate colors more discernible.

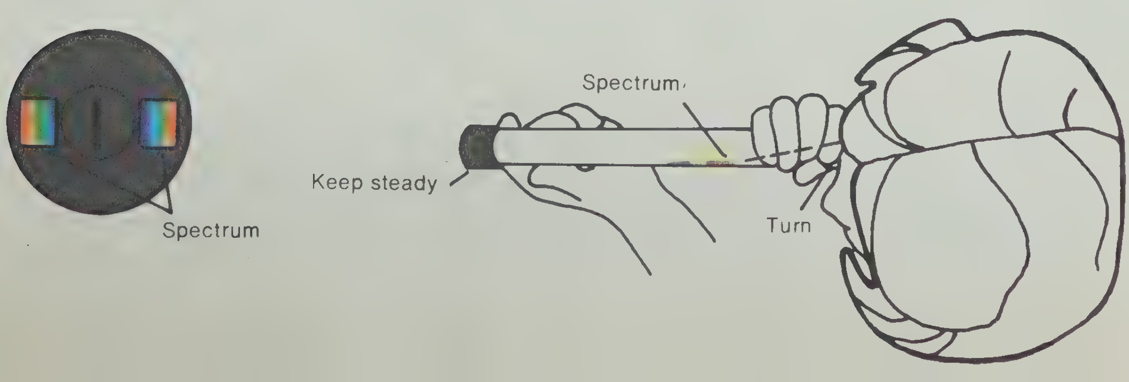
Safety Note *Never look directly at the sun through any instrument or with your unaided eye. This can cause your eyes serious and permanent damage.*

Pick up a spectroscope from the supply area. Examine the spectroscope. Identify the eyepiece and the slit end. Be careful not to touch the plastic disk in the eyepiece. The oil from your skin can soil the disk and ruin the spectroscope. If the eyepiece is dirty, it can be cleaned with alcohol and tissue.

ACTIVITY 1-1. Lay a sheet of white paper in a patch of direct sunlight. (This is a safe way to observe sunlight.) Point the slit end of the spectroscope toward the paper. The slit should point up and down. Hold the eyepeice snugly against your eye.



ACTIVITY 1-2. As you look through the spectroscope, look to the side of the tube until you see a *spectrum* (rainbow) clearly. Turn the eyepeice, without turning the slit, until the spectrum is as wide as you can make it. Cup your hand around your eye to close out as much outside light as possible.



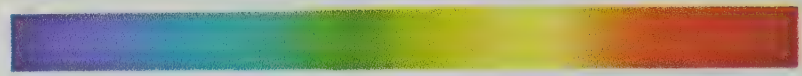
1-6. Answers will vary according to visual acuity and care in observation. Red, orange, yellow, green, blue, violet (or more or less) should be named. The student can begin at either end of the spectrum, but the order is important.

1-7. The order of the list of colors should be the same or exactly reversed. The number of colors listed, however, may well vary. It would probably be possible to list a large number of colors depending on the gradations. For instance, in the color system devised by Albert Munsell, there are 20 different colors, which he calls hues. When degrees of brightness and richness of color are considered, the result is 427 different color samples in the system.

☐ **1-6.** List the colors of the spectrum of sunlight. Put them in order.

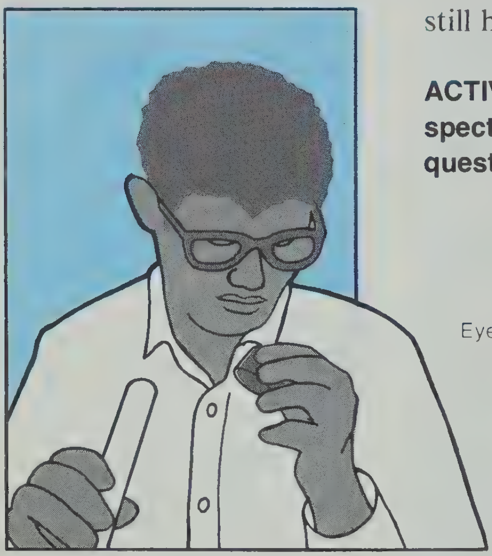
☐ **1-7.** Compare the number and order of your list of colors with those in Figure 1-1.

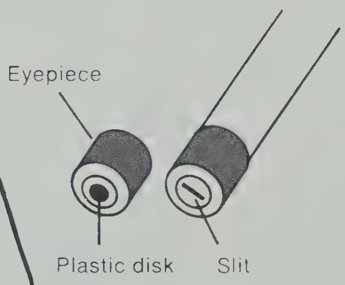
Figure 1-1



If the photograph looks different from the spectrum you saw in the spectroscope, try the experiment again. If you still have trouble, ask your teacher or a classmate for help.

ACTIVITY 1-3. Remove the eyepiece and the slit end from the spectroscope. Experiment with them until you can answer question 1-8.





Note: *Be careful to keep your finger off the plastic disk in the eyepiece.*

1-8. The plastic disk (diffraction grating) is the primary cause. Using just the disk, a rather broad, faint spectrum is visible when one looks toward a light source (but not toward the sun). Students may also note a spectrum formed when light is reflected from the disk. The same effect can be noted when light reflects from an LP record. If you have one handy, you might want to show this to them.

☐ **1-8.** Which causes the spectrum to appear, the plastic disk or the slit? How do you know?

☐ **1-9.** Describe what you did to get your answer to question 1-8.

CONTINUOUS SPECTRUM

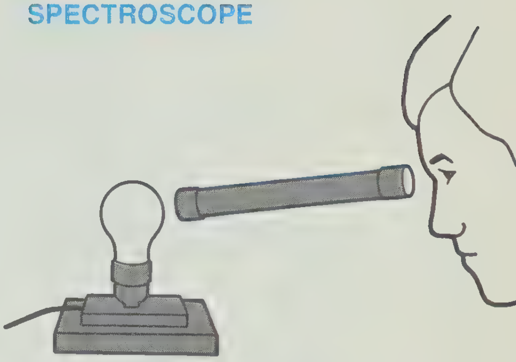
The plastic disk is called a diffraction grating. Thousands of tiny parallel lines have been marked on it. These lines cause the light to spread out into the color spectrum you've seen. This kind of spectrum is called a *continuous spectrum*. This

means one color continues right into the next. You've seen continuous spectra many times. Light reflecting from an LP record is an example. So is a rainbow.

USING THE SPECTROSCOPE

Earlier, it was said that sunlight carries information about the sun. You've also seen that sunlight can be spread out into a spectrum. Is the spectrum of the sunlight like the spectra of other sources of light? The spectroscope can help you find out. Compare the spectrum of sunlight with the spectra of an incandescent bulb and a fluorescent bulb.

In your classroom your teacher has set up an incandescent bulb. Carry your spectroscope to this area. Use it to look carefully at the light from the bulb.



☐ **1-10.** In the space provided in your Record Book, write the colors produced by the bulb. List the colors in the order you see them in the spectrum.

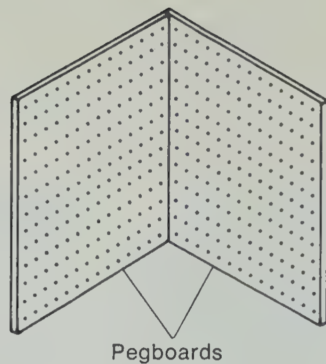
The classroom may have incandescent lights that the student can observe. If not, use the 150-watt bulb and the receptacle. Put it on a table adjacent to a wall outlet. Try to have it located so that daylight will not be observed at the same time. Likewise, you may have fluorescent lighting that can be observed in the room. If not, the student may have to be sent to a kitchen, laboratory, etc., where a tube is located. The student should see a continuous spectrum, with several pronounced bright lines superimposed. Most outstanding should be yellow, green, and violet lines.

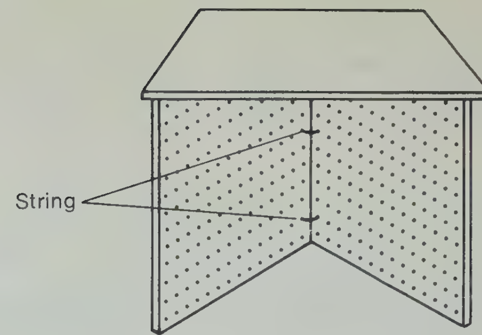
If you find any differences between this spectrum and the one produced by sunlight, list them. See if certain colors show up strongly. Are there any bright or dark lines?

☐ **1-11** Next, use your spectroscope to examine the light from a fluorescent tube. Again, list the colors in the spectrum as you see them. Also, describe any differences between the spectra from the fluorescent tube and the one from sunlight.

Did you notice bright lines in the fluorescent-tube spectrum? Did you see these lines either in the sun's spectrum or in the spectrum from the incandescent bulb? Did some of the colors show up clearer in one spectrum than in another? These differences are like fingerprints. They help astronomers distinguish one substance from another. But how?

To find out, you'll need to work with a partner. You will be using the spectroscope to look at the light given off from different heated substances. You will need to work in semidarkness. If a part of your room cannot be darkened, then rig your own work space as shown in Activity 1-4.





For Activity 1-4, use the two 10-cm pieces of string to tie the vertical pegboard backs together.

ACTIVITY 1-4. Set up two pegboard backs as shown. Put another piece of pegboard or other nonburnable shield across the top of the pegboards. This will give you more shade. If possible, cover the pegboard with black paper.

Clean baby-food jars or other containers may be used in place of the petri dishes, if desired.

Hotter burners will give better visual results. Use Bunsen or propane burners if available. If you have a demonstration spectroscope, you may want to set it up to help students verify their work. Lines are difficult to see with small burners and spectroscopes.

Now get the following materials from the supply area:

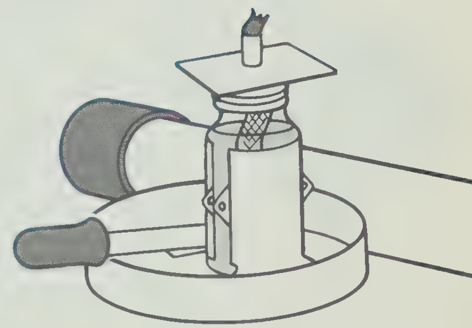
3 pieces of nichrome wire, each 10 cm long
3 alcohol burners
3 petri dishes
1 spectroscope
1 small container of distilled water
1 medicine dropper
3 pieces of masking tape, each 3 cm long
Lithium chloride crystals
Strontium chloride crystals
Sodium chloride crystals
2 pieces of string, each 10 cm long

Caution *In the next few activities you will use an alcohol burner. Be sure you understand these safety rules before you start using the burner:*

1. *The height of the wick should be about 4 millimetres except as noted in Activity 1-5.*
2. *The burner should never be more than half-filled with alcohol. Don't overfill it. For safety and economy, always keep the cap on the burner when it is not in use.*
3. *Don't leave your work area or move the burner without putting out the flame.*

4. *Be careful not to spill any alcohol when filling the burner. If you do spill some accidentally, wipe it up quickly with a paper towel.*
5. *All books, papers, and other flammable materials should be kept away from open flames. Avoid reaching across or leaning over a lighted burner.*
6. *Long hair must be tied back. Wear safety goggles during experiments involving heating.*
7. *Don't point the open end of a test tube at yourself or others while heating it. Never heat a closed container.*
8. *Be careful not to tip over the burner or the container of water. Remember that glass breaks and broken glass cuts.*

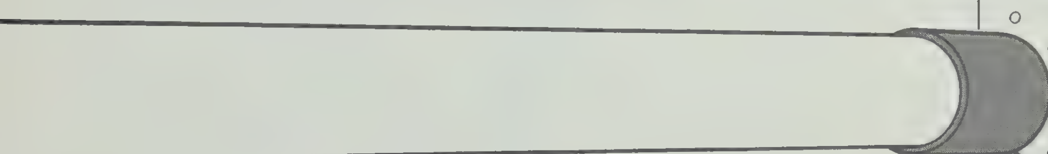
In case of an accident, notify your teacher immediately.

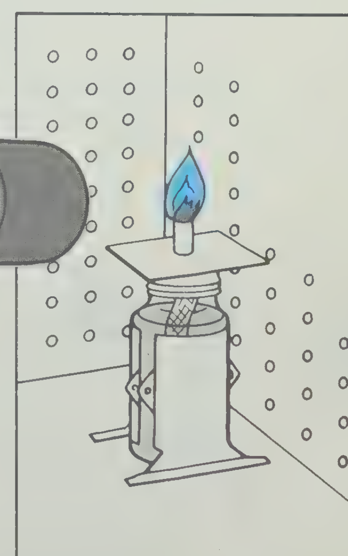


ACTIVITY 1-5. Pull 1 cm of the wick out of the alcohol burner. A well-trimmed wick should not be black at the end. Light the burner. Look at the spectrum of the flame with your spectroscope. (It's likely to be very faint.)

☐ **1-12.** Compare the spectrum of the alcohol lamp with the spectrum of sunlight.

☐ **1-13.** Did you see any bright lines in the spectrum of the alcohol lamp? If so, what colors were they?



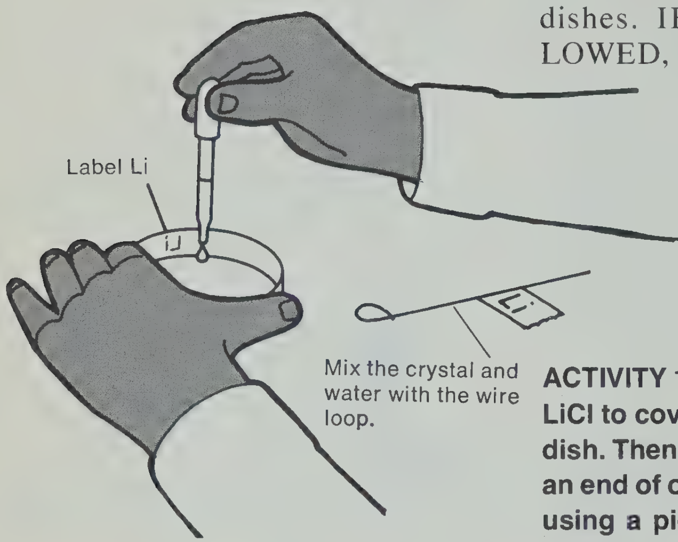


Now you are ready to do some chemical fingerprinting. You'll be comparing three substances: lithium chloride (LiCl), strontium chloride (SrCl), and sodium chloride (NaCl). You'll look at their spectra as each of these substances is heated in a flame.

LiCl, SrCl, and NaCl are compounds. The first symbols (Li, Sr, and Na) represent the elements that produce the colored lines you will see by using the spectroscope. The Cl

part of the compounds does not influence what you will see. It is very important that you keep the chemicals pure. Make sure to start with clean petri dishes. Each dish should be clearly labeled.

Place only LiCl in the Li dish, SrCl in the Sr dish, and NaCl in the Na dish. Also, be sure that the labeled wires you use are clean. Place them *only* in the appropriate dishes. IF THESE PROCEDURES ARE NOT FOLLOWED, YOUR RESULTS WILL NOT BE CORRECT.



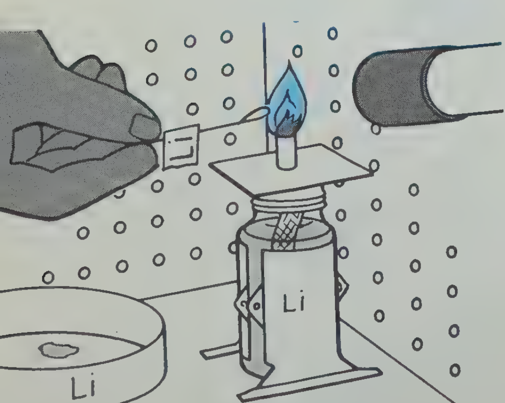
Labeled wires can be placed in envelopes in sets, and the envelope can be hung on a pegboard. See note below for directions on how to clean nichrome wires.

ACTIVITY 1-6. Label a small dish "Li." Get enough crystals of LiCl to cover a spot this size ●. Put the crystals of LiCl in the dish. Then add 2 drops of distilled water. Make a small loop in an end of one of the nichrome wires. Label the wire as shown, using a piece of masking tape. Mix the water and crystals, using the wire loop. Leave the wire in the dish. Use this loop *only* with the LiCl compound.

Keep wicks well trimmed. If salts get on the wicks, trim with scissors. Caution students to use labeled burners with the appropriate chemicals.

The spectra from the three chemicals are faint. Have students hold the spectroscopes as close as possible to the flame.

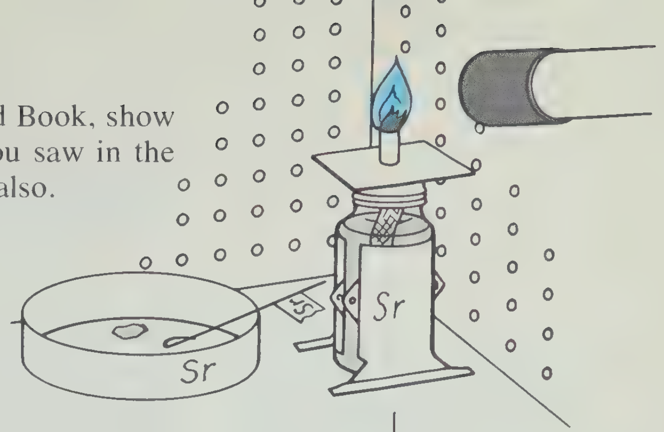
Very small amounts of lithium chloride, strontium chloride, and sodium chloride are all that is necessary. In this and the succeeding activities, it is most important to avoid contamination of the samples and to keep solutions from getting on the wick of the burner. The nichrome loops, once made, can be reused by other students if they are kept with the respective samples. Loops may be cleaned by rinsing in clean water, dipping in concentrated HCl, and heating in the flame until they show no color.



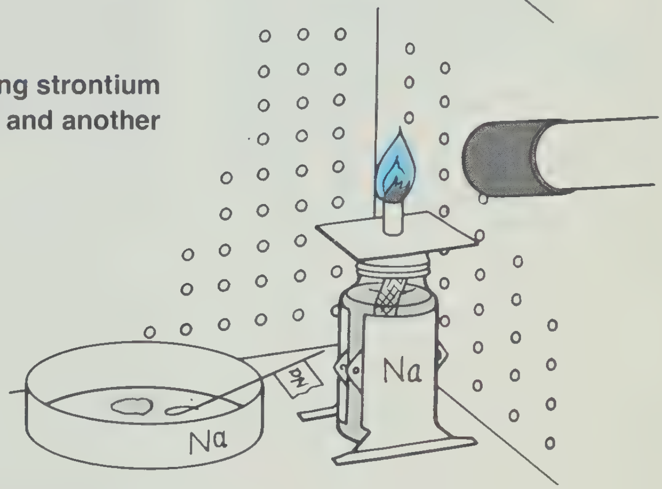
ACTIVITY 1-7. Label a burner "Li." Use it only with LiCl. Dip the loop of nichrome wire into the lithium chloride solution. While your partner looks at the spectrum of the alcohol flame, put the loop into the flame. *Do not touch the wick with the loop. Try not to get any chemicals on the wick.* Repeat this procedure until one or more colored lines can be seen. Take turns looking at the spectrum.

☐ **1-14.** In the space provided in your Record Book, show the position and color of any bright lines you saw in the spectrum. Do this for Activities 1-8 and 1-9 also.

You may want to have colored pencils or crayons available so that students can show the spectral lines in color. Some lines are especially difficult to see. Encourage students to try hard but not to spend the whole period searching for a line.



ACTIVITY 1-8. Repeat Activities 1-6 and 1-7, using strontium chloride crystals. Use a clean dish, a clean wire, and another alcohol burner. Label all three items "Sr."



ACTIVITY 1-9. Repeat Activities 1-6 and 1-7, using sodium chloride crystals. Use the third clean dish, clean wire, and alcohol burner. Label all items "Na."

Recall that you were looking for chemical fingerprints of the compounds.

☐ **1-15.** Look at your answers for question 14. Were your spectra drawings different for LiCl, SrCl, and NaCl?

Compare your findings with the spectra shown in Figure 1-2.

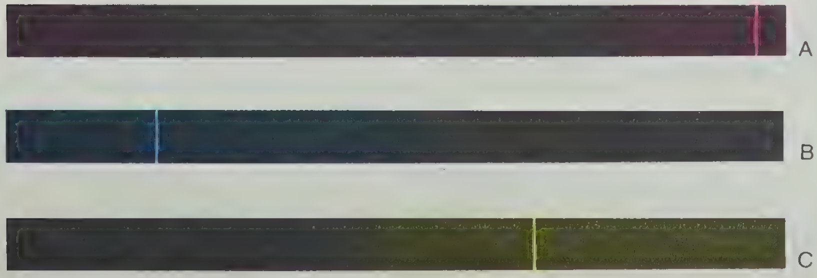


Figure 1-2

☐ **1-16.** Match the spectra from Figure 1-2 with the chemicals you observed.

LiCl______
SrCl______
NaCl______

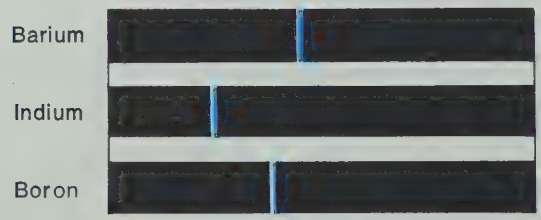
You might want to ask students how they could be sure that the bright lines were due to the lithium, strontium, or sodium, and not to the chloride. You could have a sample of sodium carbonate (washing soda) or sodium bicarbonate (baking soda) that they could try in the flame with a clean wire. They will see the bright sodium lines. Incidentally, students will probably show a single yellow line for the sodium spectrum. This is as it should be. There are actually two bright lines, but they are so close together that the simple spectroscope cannot resolve them.

The spectrum of an element heated in a colorless flame is a few bright lines. This type of spectrum is called a *bright-line spectrum.* Each element produces a definite set of bright lines. The bright lines you saw earlier in the fluorescent-tube spectrum were due to the gases in the tube (mostly mercury vapor). Scientists can identify an element by its bright lines as surely as you can be identified by your fingerprints. You have seen how certain elements can be identified in this way.

If you had good results with Li, Sr, and Na, your answers to question 1-15 should have been:
LiCl_A_, SrCl_B_, and NaCl_C_.

Other examples of bright-line spectra are given in Figure 1-3.

Figure 1-3



☐ **1-17.** Remember the "how" question 1-1? Can you answer it now? If so, do it.

Astronomers use spectroscopes to identify the elements in the stars. In fact, the spectral lines of the element helium were first observed in sunlight. When this substance was found on the earth, it was named helium (from the Greek word *helios,* meaning "sun"). The spectrum of helium is shown in Figure 1-4.

Figure 1-4

Perhaps you would like to learn more about the kind of spectrum shown in Figure 1-4.

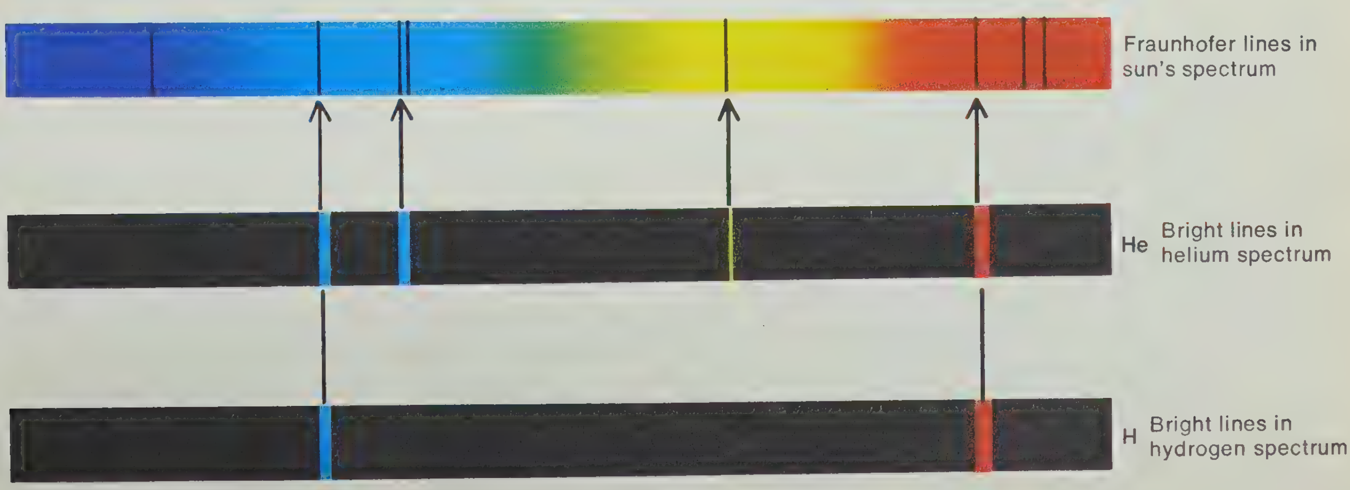
The dark lines that cross the spectrum of the sun were first investigated by Fraunhofer in 1814. He measured but couldn't explain the positions of a great many of them. The lines are now called *Fraunhofer lines* in Fraunhofer's honor. But their explanation was the product of another great scientist, Kirchhoff.

Gustav Robert Kirchhoff (1824-1887) also was a German physicist. He is perhaps best known for his Law of Thermal Radiation and his rules for calculating currents in electrical networks.

It was found that these dark lines on the spectrum were in exactly the same position as the lines in the bright-line spectra of certain elements. Light from the sun's surface passes through the gases in the atmospheres of the sun and the earth. It is believed this causes the dark lines. Figure 1-5 shows a comparison between the two kinds of lines.

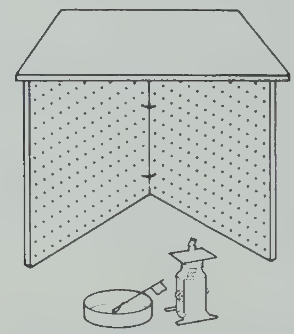
The spectrum of the light from the sun has been photographed, and the positions of the dark lines noted. These lines have been compared with known spectral lines. In this way astronomers can predict what elements the atmosphere of the sun contains.

Figure 1-5



Bright and dark lines in spectra tell astronomers much about what stars and planets are made of. Most of what we know about the sun and its atmosphere comes from spectrum information. It's the message we get from sunlight.

From time to time in this module you will be asked to do Problem Breaks. These are special problems for you to solve. You won't have much help from your book or from your teacher. The problems will help you understand more about what you are studying in the chapter. But that's not their major purpose. They are designed to give you practice in problem solving, and in setting up your own experiments. Do every Problem Break—even the tough ones. In most cases, you should have your teacher approve your plan before trying it. The first Problem Break in this module is coming up next.



"unknown"

Problem Break 1-1 calls for the student to identify substances from the spectra they produce. A suggested procedure is as follows:

Use three separate, clean petri dishes or baby-food jars and three separate burners. In the first dish, make a solution of a mixture of sodium chloride and lithium chloride; in the second, use a mixture of sodium chloride and strontium chloride; in the third, use strontium chloride and lithium chloride. Have a clean wire with each, and number the containers and the wires 1, 2, and 3. Be sure to keep track of your mixtures by number, so that when students check their prediction with you, telling the number used, you can match them up. It might be wise to prepare containers of the three mixtures and put out only a small amount at a time. This would help guard against contamination. A different complete setup for each mixture would be best.

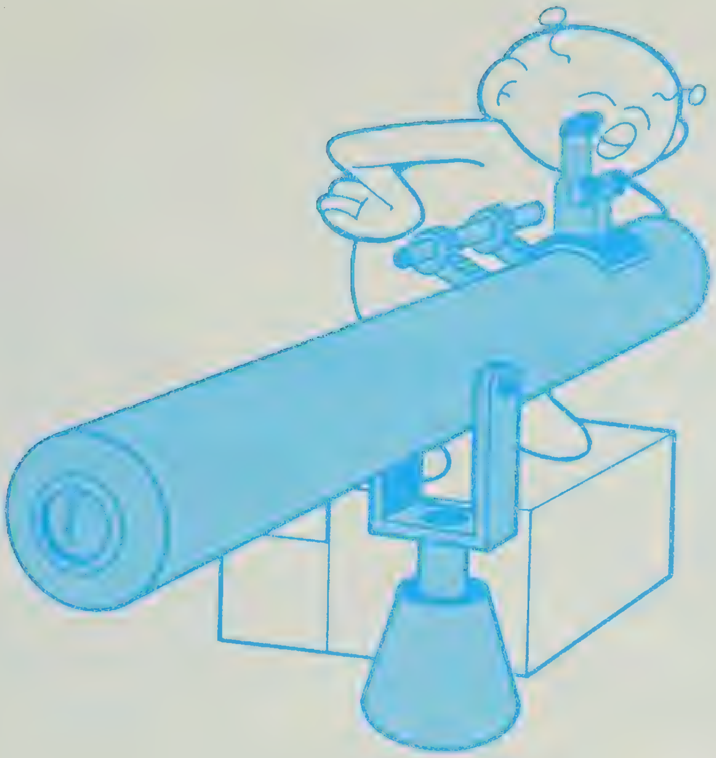
PROBLEM BREAK 1-1

Here's some detective work for you. Your teacher has prepared a solution of one, two, or three of the substances you just tested (sodium chloride, lithium chloride, and strontium chloride). Your job is to find out which substance or substances were used.

☐ **1-18.** In your Record Book, show the position of any bright lines you identify.

☐ **1-19.** Compare the sketch you made with the sketches you made in answer to question 1-14. What substance or substances do you predict are in the unknown solution?

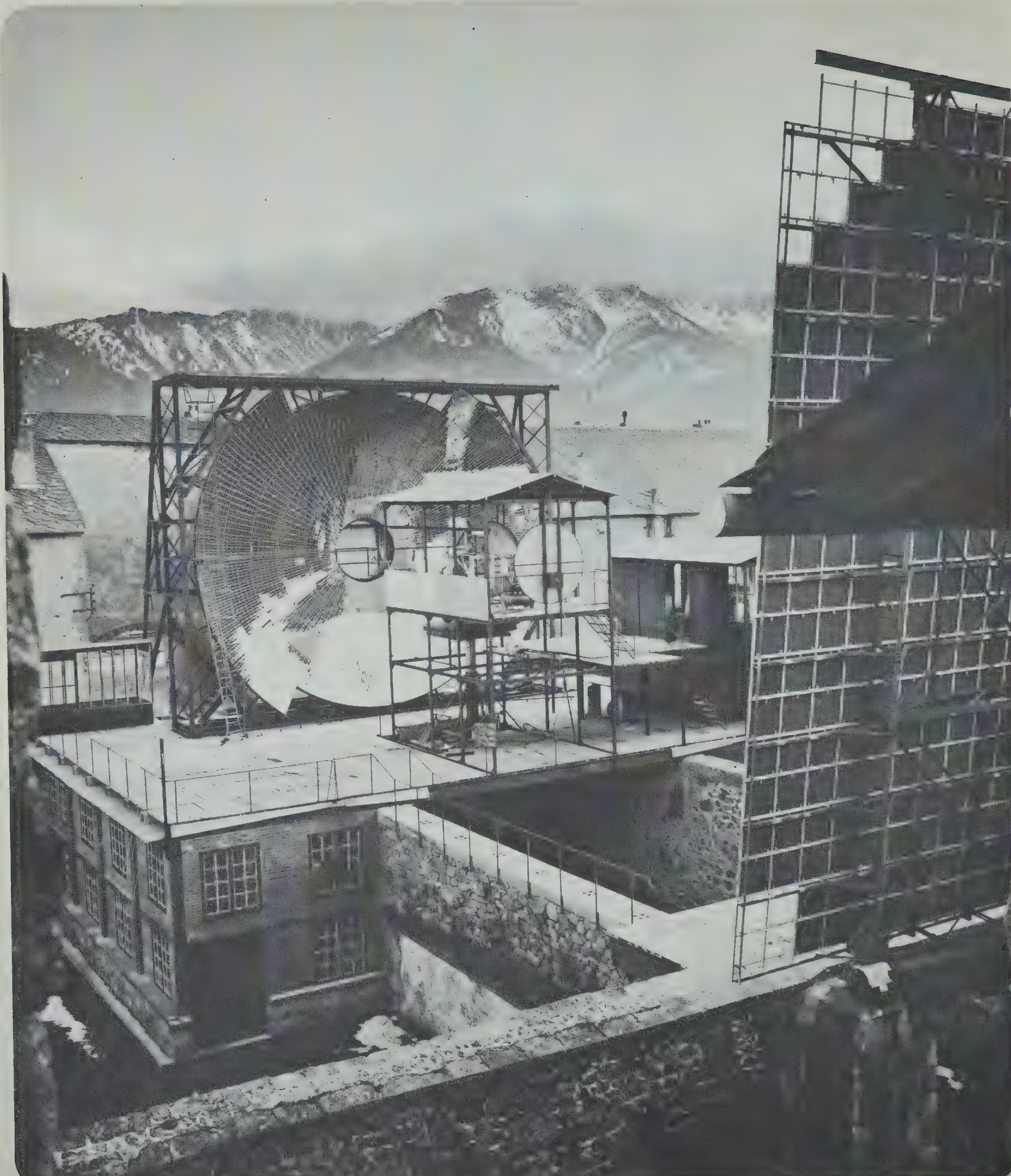
Check your prediction with your teacher.



Before going on, do Self-Evaluation 1 in your Record Book.

GET IT READY NOW FOR CHAPTER 2

You will need 6-cm × 3-cm copper strips. These should be cut from the 30-cm × 30-cm copper sheets that are supplied. Each sheet will yield 50 strips. Probably one sheet will suffice, as the strips can be reused by other students once they are cut to size. You will need to make provisions for extension cords from the wall outlets if power is not available at the student stations. Students will be using 5 or more receptacles with various wattage bulbs for extended times in the chapter. Depending on how widely spread your students are, you might want to consider procuring additional receptacles to augment the 5 that are furnished. Any screw-type socket receptacle that will hold a light bulb upright can be used. You will need paper clips and matches, which must be supplied locally.



Watt's Hot?

2

EQUIPMENT LIST

Per student-team

1 copper strip, 6 cm × 3 cm
1 Celsius thermometer
1 paper clip
1 socket receptacle
1 150-watt bulb
1 100-watt bulb
1 60-watt bulb
1 50-watt bulb
1 metrestick
1 pegboard back

Per class

Pieces of dowel
Candles
Matches

CHAPTER EMPHASIS

Using a simple radiant-energy measurer, the student determines the variables that affect the readings, and compares the energy received from the sun with that from an incandescent bulb at a particular distance.

Excursion 2-1 is keyed by a Checkup.

Everybody knows that the sun gives off lots of energy. In fact, all energy on the earth comes, in one way or another, from the sun. But what does it mean to say "lots of energy"? How much is "lots"? And how do you find out how much? That is the problem for this chapter—how to measure the energy the sun gives off.

You need to know some things about energy before you begin. The following checkup will help you find out whether you are ready to go ahead.

MAJOR POINTS

1. A solar-energy measurer (pyrheliometer) can be constructed.
2. Temperature change can be used as a measure of radiant energy received.
3. The temperature change of the solar-energy measurer varies with time, up to a certain point.
4. The amount of energy received varies with the wattage (energy per second) of the bulb.

This chapter might be considered the most important one in the module. Using simple apparatus that the students construct themselves, a very realistic measurement can be made that will lead to finding the power of the sun in a later chapter. Those who are well-versed in physics may object to the apparent discrepancy of terms. Energy is measured in joules (or newton • metres) whereas the watt is a measure of power in joules per second. Time, therefore, is the factor connecting the two terms. Experience has shown that the disparity presents no serious problems for the students, however, and the matter is resolved in a later chapter. Incidentally, you probably will want to have 2 or 3 students working together on the activities.

CHECKUP 2-1

In your Record Book, place a check mark in front of each correct answer. There may be more than one correct answer per question.

1. Work is
a. force.
b. distance.
c. force × distance.
d. speed × time.

2. A measure of energy is
a. force.
b. force × distance.
c. speed × time.
d. work.

3. Energy can
a. exist only in the form of heat.
b. exist in more than one form.
c. be transferred from one system to another.
d. cause changes in matter.

4. Energy is always
a. conserved.
b. destroyed.
c. needed to overcome forces.
d. a measure of the time needed to do work.

Checkup. In order to understand the purpose of this chapter, the student needs an elementary concept of energy. Those who did not participate in Levels 1 or 2 of *The Natural World*, or who have forgotten, will profit from doing Excursion 2-1, a review of the energy concept. This Checkup is the mechanism for getting them into the excursion. You may want to check answers to the four questions, to see that those who need help are getting it.

EXCURSION

Check your answers on page 24 of **Excursion 2-1,** "Energy at Work."

To begin making a sun-energy measurer, you will need the following:

1 strip of copper, 6 cm × 3 cm
1 Celsius thermometer
1 piece of dowel, the same diameter as the thermometer bulb
1 candle
Matches
Paper clip

RESOURCE

Do you know how to use the metric system? If not, do **Resource 1,** "Measuring Distance in Metric."

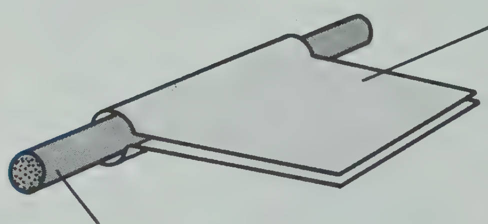
In the interest of economy, you will probably want to have the copper strips precut instead of having each student cut one. Note that the piece of dowel, candle, and matches are "classroom" items, and can be kept on the supply table to be used only when needed.

If reasonable care is taken in bending the copper, not only will it fit tightly around the thermometer bulb, thus transferring maximum heat to the bulb, but also it will be reusable by other students.

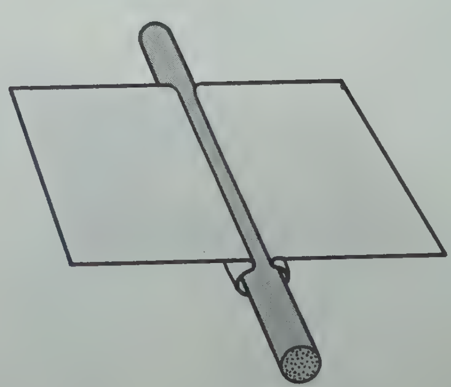
How much the temperature of an object increases also depends on its specific heat. But this factor is not vital to the experiments in the chapter, as long as the object is allowed to heat to its equilibrium temperature.

2-2 and 2-3. The copper strip should increase in temperature. The thermometer should measure the increase. (Note, however, that the thermometer does not measure the heat content of the copper, but only one factor of it.)

ACTIVITY 2-1. Pinch the strip of copper tightly around the dowel as shown.



ACTIVITY 2-2. Bend the ends of the copper back flat.



The part of the sun's energy that reaches the earth is in the form of light. Most of this light energy changes to heat energy when it reaches the earth. This heating effect of light is what causes objects in sunlight to get hotter.

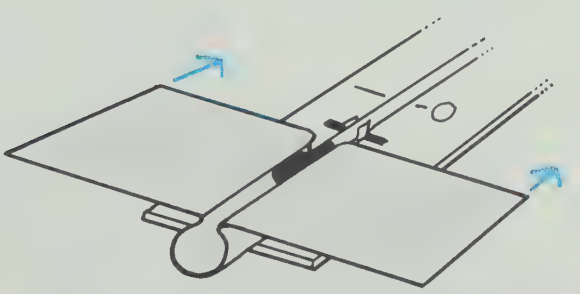
☐ **2-1.** How much an object's temperature changes when exposed to sunlight depends on a number of things. Which of the following things do you think could affect this change?

A. How big the object is
B. How well it absorbs heat
C. How quickly it conducts heat
D. How long it is heated

Each of those affects how much change in temperature will be observed when the object is placed in the sun.

You can get an idea of how much heat is absorbed by an object. Just measure its temperature before and after placing it in the light. All you need is an object to be heated, and a thermometer.

ACTIVITY 2-3. Slide the copper strip from the dowel and under the bulb of the thermometer. Gently pinch it around the bulb. *Use care so as not to break the thermometer.*



You've probably figured out how your sun-energy measurer will work.

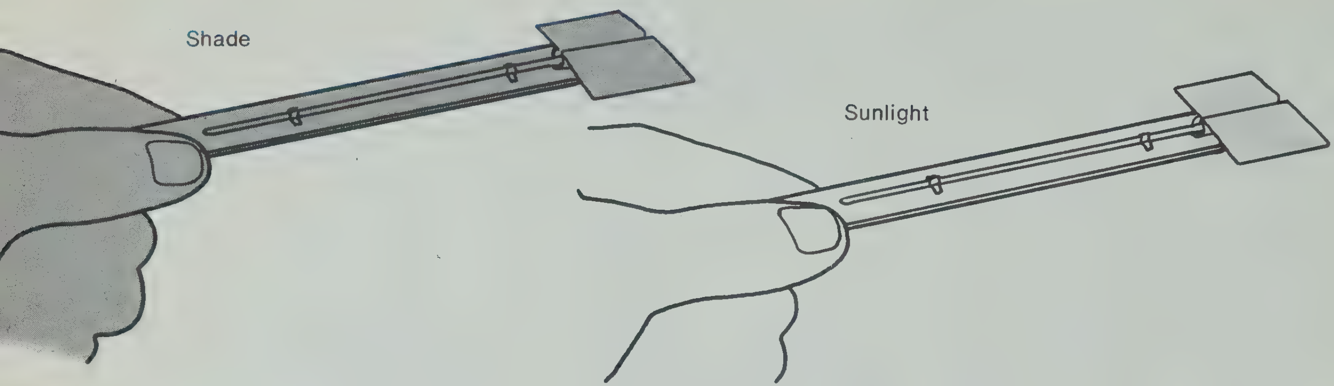
☐ **2-2.** What do you predict will happen to the copper strip if it is placed in sunlight?

☐ **2-3.** What is the purpose of the thermometer?

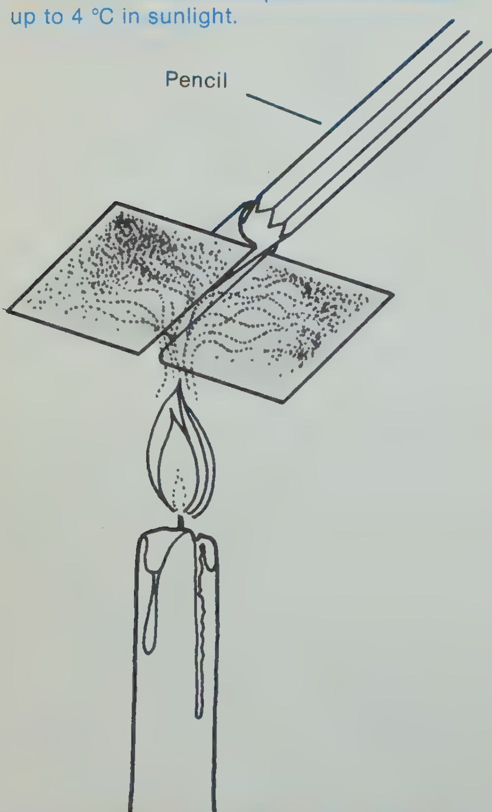
Now let's test the sun-energy measurer you've built.

The reason that it should not rest on any surface is that heat could be conducted to or from it more readily, as well as being reflected to it. Of equal importance, however, is protecting it from the wind or from drafts.

ACTIVITY 2-4. Hold the instrument in the shade for 2 minutes. Then move it into the sun for about 5 minutes. Do not rest it on any surface. This will give poor results.



2-4. It should show a temperature increase of up to 4 °C in sunlight.



Carbon black is preferred to black paint because it tends to be a better absorber and conductor of heat energy. It can be messy, however, and students may have to be warned about keeping their fingers out of the soot.

☐ **2-4.** Was the thermometer reading in the shade different from that in the sun? (If so, how much?)

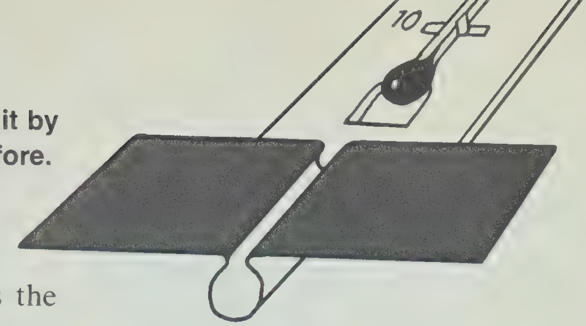
If the thermometer didn't show a temperature change, something is wrong. The copper strip should have absorbed enough energy to affect the thermometer. If it didn't, check Activities 2-1, 2-2, and 2-3, to be sure that you put the instrument together correctly.

You can improve your sun-energy measurer. You probably noticed that the temperature change was slow. The amount of temperature change was probably rather small, too. It would help matters if the copper absorbed energy more quickly than it does.

Copper is a shiny metal. This means that it reflects some light. By cutting down its shininess, the copper would convert more light energy to heat.

☐ **2-5.** What could you do to the copper to make it absorb more of the sun's energy?

ACTIVITY 2-5. Slide the copper strip off the thermometer. Insert a pencil or dowel in the bend of the strip. Hold the copper over a lighted candle. Try to cover the flat surface evenly with soot from the candle. *Warning: Do not hold the thermometer over the candle. It will get hot and break.* If you get wax on the strip, you must clean it and start again.



ACTIVITY 2-6. Let the copper strip cool. Then, holding it by the unblackened loop, attach it to the thermometer as before.

Test your instrument in a sunny spot.

☐ **2-6.** At room temperature, what temperature does the sun-energy measurer show?

☐ **2-7.** What temperature does the instrument show after being in direct sunlight for a few minutes?

☐ **2-8.** By how many degrees did the temperature change?

Remove the sun-energy measurer from the sunlight. Let it return to room temperature.

☐ **2-9.** Why do you think copper was a good choice of metal?

2-9. Probably the most important reason is that copper is a good conductor of heat. Also, from a practical standpoint, it is easily shaped (malleable).

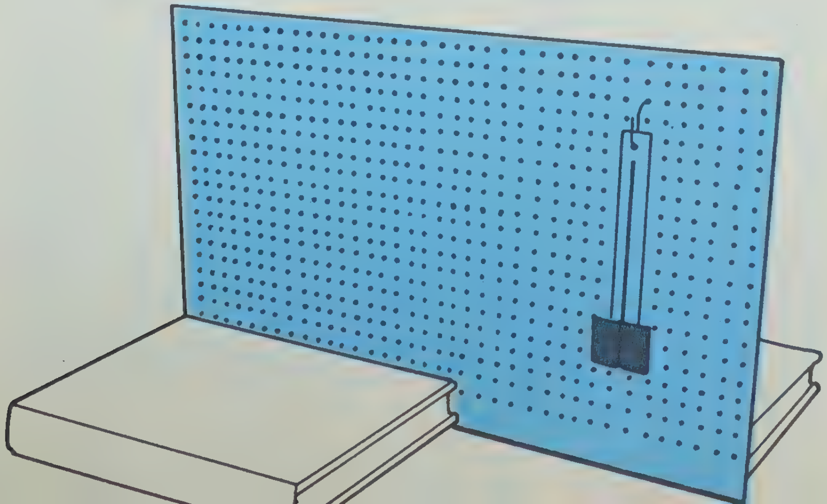
This instrument should help tell you how much sun-energy is received by the copper strip in a given amount of time.

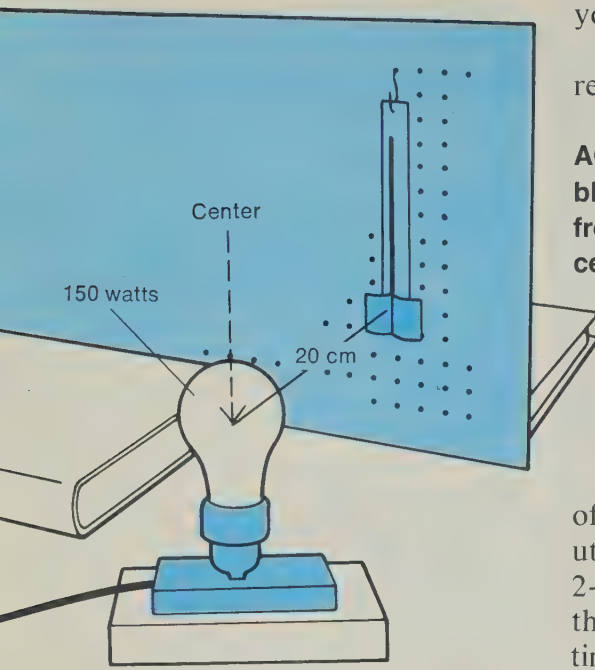
You may see some problems in using the sun-energy measurer. Suppose you got a reading in the sun 20° higher than in the shade. This would tell you that the copper strip had absorbed energy. But it would not tell you how much total energy the sun gives off. To learn that, you would need to know other things. The next activities will help you find out what they are. Pick up a pegboard and a paper clip.

In making readings of temperature change with the pyrheliometer throughout the chapter, be sure that students measure the change under constant conditions. For example, if the amount of change in sunlight is made outside, then the beginning temperature should also be read outside. If the change is to be measured indoors (as on a window ledge, with sunlight coming through the glass), then the beginning temperature should be that of the room.

ACTIVITY 2-7. Hang the sun-energy measurer in an upright position as shown. Make a hanger from a paper clip.

In this activity and the ones that follow, the books may be placed at the other end of the pegboard, away from the instrument.





Carry the stand with the attached instrument to where your teacher has set up some light bulbs.

You will use these bulbs as a light source. They will represent the sun.

ACTIVITY 2-8. Place the pegboard near a 150-watt bulb. The blackened surface of the copper strip should be 20 cm away from the center of the bulb. It should also be level with the center of the bulb. Don't turn on the light yet.

Have students adjust the height of the pyrheliometer so that the copper strip is on the same horizontal level as the center of the light bulb.

Record the temperature of the thermometer in Table 2-1 of your Record Book. This is the temperature at 0.0 minutes. It goes in the first row of the middle column in Table 2-1. When you turn on the lamp, you will start recording the temperature every 0.5 minute (30 seconds). Check the time. Then turn the light on. Leave the light on for 5 minutes. Complete the middle column of the table.

Table 2-1

The students are determining the equilibrium temperature of the strip and the time required to reach it. Thus time is one of the variables asked for in question 2-13 on the next page. Other variables named might be size (wattage) of the bulb, distance to light source, angle at which light strikes the strip, and size of the strip.

Be sure to check the "Total temperature change" column for each student. These data are critical for the following graph and questions.

Time (minutes)	Temperature (°C)	Total temperature change (°C)
0.0		
0.5		
1.0		
1.5		
2.0		
2.5		
3.0		
3.5		
4.0		
4.5		
5.0		

☐ **2-10.** What is the highest temperature you recorded during the 5 minutes?

Here's how to complete the last column of Table 2-1, the "Total temperature change."

For each row, subtract the temperature at 0.0 time from the temperature recorded at the new time.

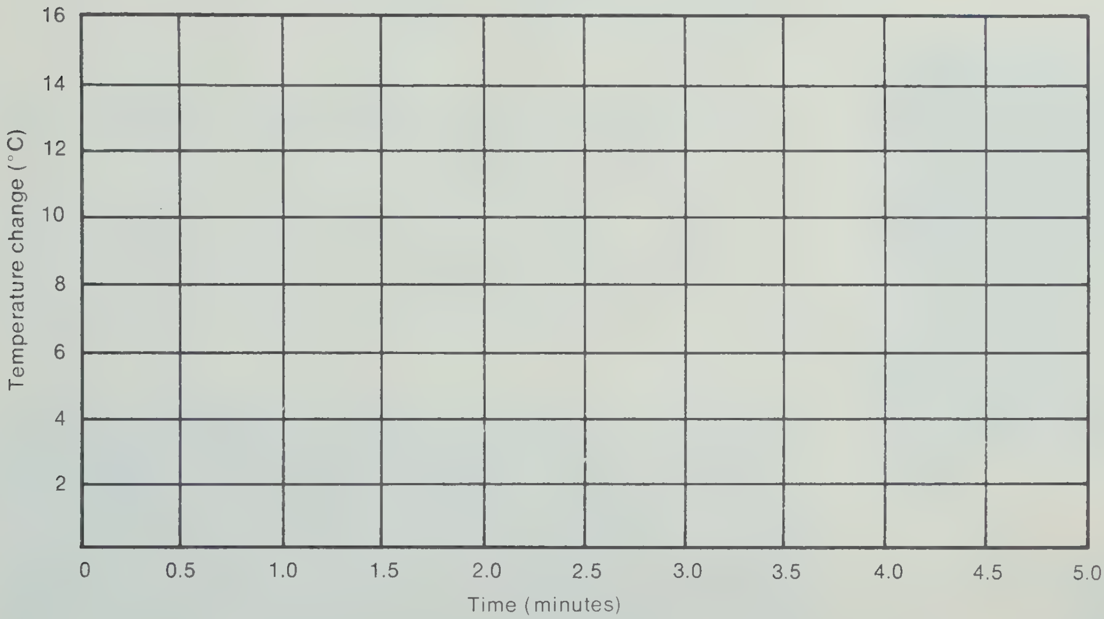
Example: Suppose the temperature at 0.0 time was 24 °C, and the temperature after 2.5 minutes was 62 °C.

$$\text{Total temperature change} = 62\ ^\circ\text{C} - 24\ ^\circ\text{C}$$
$$= 38\ ^\circ\text{C}$$

Graph your results on the grid of Figure 2-1 in your Record Book. Use the data from the "Total temperature change" column and from the "Time" column. If you need help in graphing, see **Resource 5,** "Pictures of Relationships."

RESOURCE

Figure 2-1



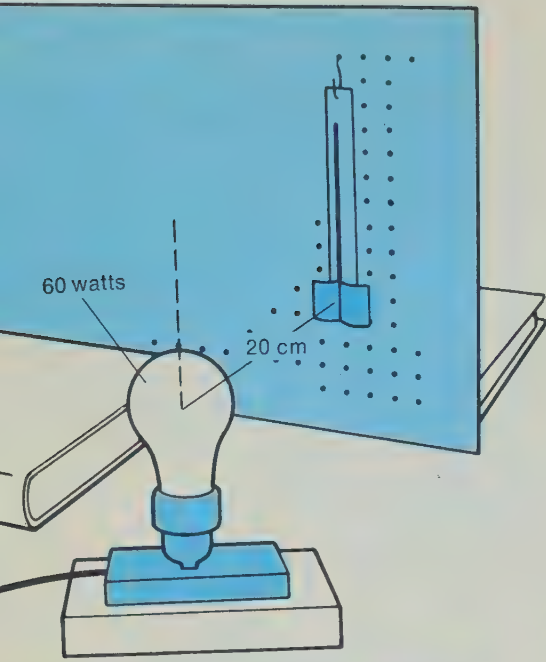
☐ **2-11.** According to your graph, how many minutes passed before the temperature stopped rising?

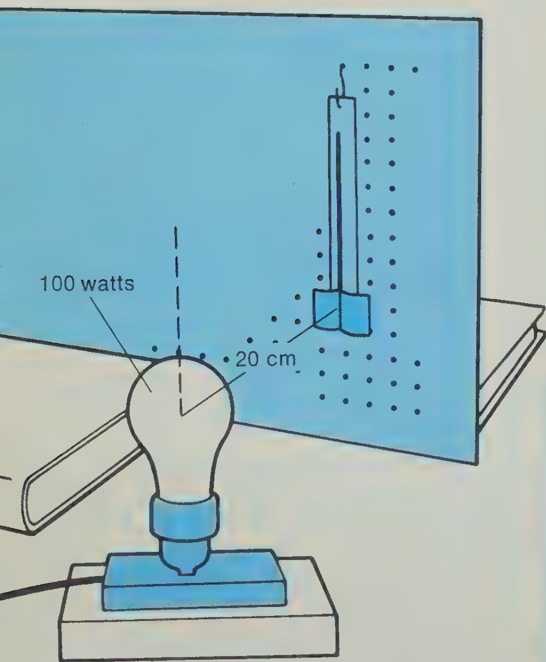
2-11. The most probable answer is 3 to 3½ minutes.

☐ **2-12.** Why, do you think, did the temperature stop increasing?

2-12. Equilibrium temperature was reached when the amount of heat lost by the strip equaled the amount of heat gained. This is a good concept to be acquired, but don't expect many students to achieve it.

Place the sun-energy measurer away from the light so that it can cool to room temperature.





☐ **2-13.** List at least three variables that you think might have affected how much temperature change you observed.

You should investigate the effects of different amounts of light energy on the sun-energy measurer. You can use light bulbs of different sizes. Be sure to keep other variables, such as time, distance, and position of copper strip the same.

ACTIVITY 2-9. Set up the sun-energy measurer and light source as shown. *Use a 60-watt bulb* and wait until the temperature reaches its highest reading (about 5 minutes). Record the original and highest temperature readings in Table 2-2 of your Record Book.

The point does not have to be made with the student but, correctly stated, the watt number on the bulb tells how much energy it uses *per second*.

ACTIVITY 2-10. Allow the thermometer to return to room temperature. Repeat Activity 2-9, using a 100-watt bulb. Record the data in Table 2-2.

Use the original temperature from the 0.0 row of Table 2-1 on page 20 and the highest temperature, from the 5.0 row, to fill in the spaced in Table 2-2 for the 150-watt bulb.

Table 2-2

Bulb	Original temperature	Highest temperature	Temperature change
60W			
100W			
150W			

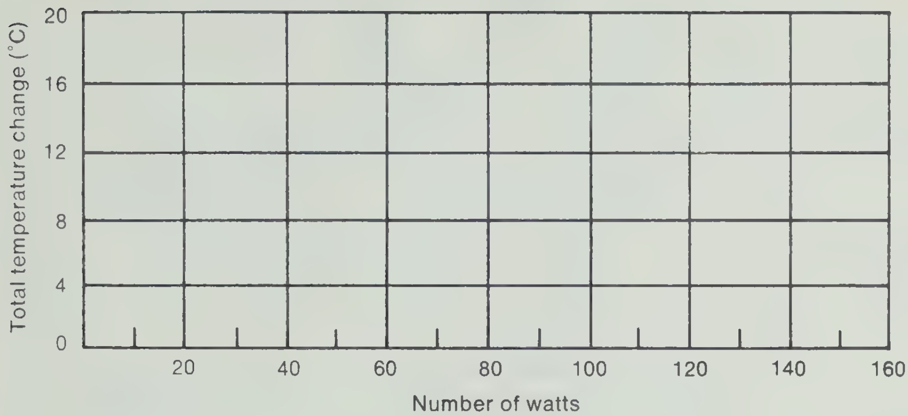
The watt number on a bulb tells you how much energy it produces. The greater the wattage, the greater the energy produced.

☐ **2-14.** Which of the following bulbs produces the most light energy: 150W, 60W, or 100W?

Complete the last column in Table 2-2, and graph your results in Figure 2-2 of your Record Book.

Figure 2-2. The graph should be a straight line. Of course, it should pass through the "0,0" point (no wattage, no temperature change) and show about 5 °C at 60W, 8 °C at 100W, and 12 °C at 150W.

Figure 2-2



☐ **2-15.** What happened to the temperature change as the wattage (amount of energy) of the bulb increased?

☐ **2-16.** Look at your graph in Figure 2-2. Predict the temperature change if you had used a 50-watt bulb.

2-16. The prediction should be about 4 °C for a 50-watt bulb.

Get a 50-watt bulb and test your prediction in question 2-16.

☐ **2-17.** Was your prediction in 2-16 correct?

☐ **2-18.** How does the size (in watts) of a light bulb affect the temperature of the sun-energy measurer?

This chapter has given you part of the answer for how to measure the sun's energy. You can compare the sun's heating power with that of a known source—a light bulb. But that isn't all there is to it. You will look at how distance relates to heating power. That's next, in Chapter 3.

Before going on, do Self-Evaluation 2 in your Record Book.

EQUIPMENT

None

PURPOSE

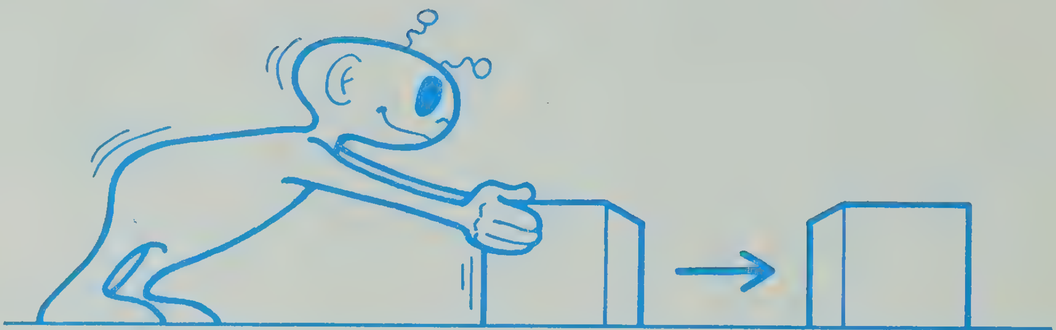
To provide a review of the energy concept.

Excursion 2-1
Energy at Work

Whenever possible, scientists use operational definitions in describing things they study. For example:

A scientific operational definition for work is

$$\text{WORK} = \text{FORCE} \times \text{DISTANCE}$$



Answers to Checkup

The correct answers for the Checkup are 1 c; 2 b, d; 3 b, c, d; and 4 a, c. Notice that some questions had more than one correct answer. If you missed any of these, or if you checked any of the other choices, do this excursion before going back to Chapter 2.

This is a remedial-review excursion. The student is led into it through the Checkup in Chapter 2.

MAJOR POINTS

1. Energy is equated to work.
2. Energy exists in different forms.
3. Energy can be transferred from one place to another.
4. Energy can be changed from one form to another.
5. Energy can cause a change in matter.
6. Energy is conserved. When it changes from one form to another, no energy is lost or destroyed.

According to this definition, Iggy (above) is doing work if he does two things:

1. Applies a force to the box.
2. Moves the box some distance.

Somehow, Iggy has the ability to do work. This ability can be thought of as something present in him. We'll call it energy. The scientist, being precise, wants a more accurate definition of energy. The scientist says, "Energy can do work."

The scientist's definition of energy has an interesting result. There are different kinds of things that can do work. Therefore, energy must exist in different forms.

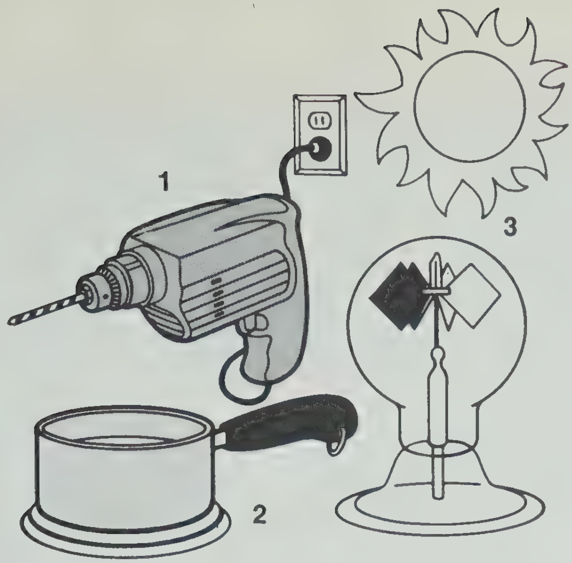
For example, electrical devices (1) can do work; therefore, electricity is one form of energy.

Heat (2) also can be used in doing work. It, too, must be energy.

Light (3) is considered as another form of energy because it can do work.

Still other forms of energy exist. Chemical energy is an example.

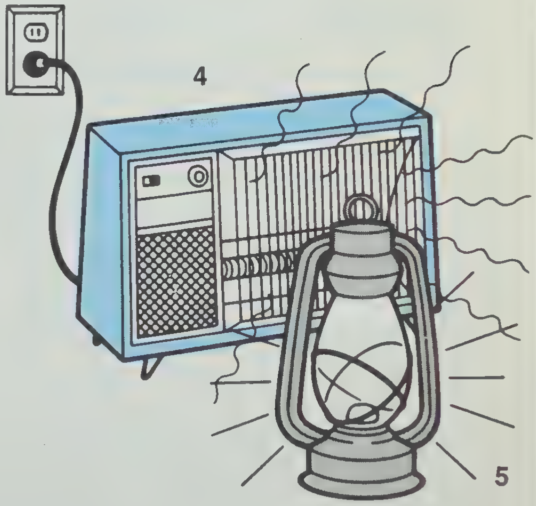
You know from your own experiences that energy can be transferred from one place to another. Light, for example, travels to the earth from the sun. A hot object next to a cold one loses heat to the cold object. Electricity can move from a power plant to the lamp on your table.



□ **1.** Give another example of the transfer of energy.

Remember, too, that energy can be changed from one form to another:

Light can be changed to heat.
Electricity (4) can be changed to light and heat.
Heat (5) can be changed to light.



□ **2.** Can you give an example of heat being changed to electricity?

□ **3.** Can chemical energy be changed to electrical energy?

□ **4.** Give an example or two of how energy causes a change in matter.

When changes in matter occur, or one form of energy changes to another, no energy is lost or destroyed. Energy may be absorbed, released, changed in form, and spread around. But it is always somewhere. It is always conserved. Scientists refer to this fact as the *Conservation of Energy*.

Return now to Chapter 2.

Lights in the Distance

3

MAJOR POINTS

1. The amount of energy received varies with the distance between the source and the solar-energy measurer.
2. In order for the energy received by the solar-energy measurer to remain constant, the radiant energy of a source must increase at a greater rate than the distance from the source increases.
3. It is possible to determine the distance from the solar-energy measurer that a 150-watt bulb must be in order to cause the same temperature change that the sun causes.
4. To measure the energy given off by the sun, it is necessary to know the distance to the sun.

EQUIPMENT LIST

Per student-team

1 150-watt bulb and socket
1 pegboard
1 sun-energy measurer (See Chapter 2.)

In Chapter 2 you learned a few facts about measuring light energy. Using light bulbs to represent the sun, you learned that the surface receiving light heats up. And you learned that the size of the light source affects the amount of heat absorbed.

Now let's test another variable. Let's see how the distance between the light source and the sun-energy measurer affects the amount of heat energy received.

☐ **3-1.** What do you predict will be the effect of moving your light source farther away from the sun-energy measurer?

Problem Break 3-1. This is the most important point of the chapter. The information that the student gets from the graph provides the answer to question 3-4. This answer in turn is the starting point for figuring the power of the sun in Chapter 8. Check student work carefully. Extra time here will be well spent.

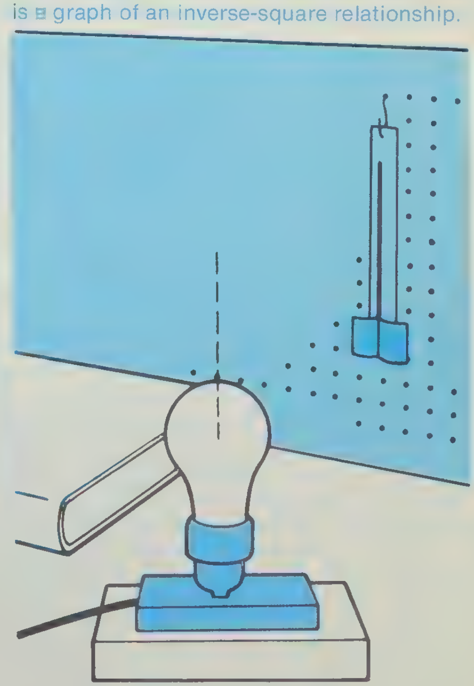
See the Teacher's Edition of the Record Book for a sample graph for Problem Break 3-1. The student graph should look similar to that. Using the answer to question 3-3 on the vertical axis, the student can read the answer for question 3-4 on the horizontal axis. This is a graph of an inverse-square relationship.

PROBLEM BREAK 3-1

Get a 150-watt bulb and test your prediction for question 3-1. How much does the reading of the sun-energy measurer change by *doubling* the distance between it and a light source? Suppose you *tripled* the initial distance. Would the temperature reading decrease to one third of what it was at the first setting? Here are some guidelines on how to find out what to do. You will need the following:

150-watt bulb and socket
1 pegboard
Sun-energy measurer

Set up the sun-energy measurer and light source as shown.



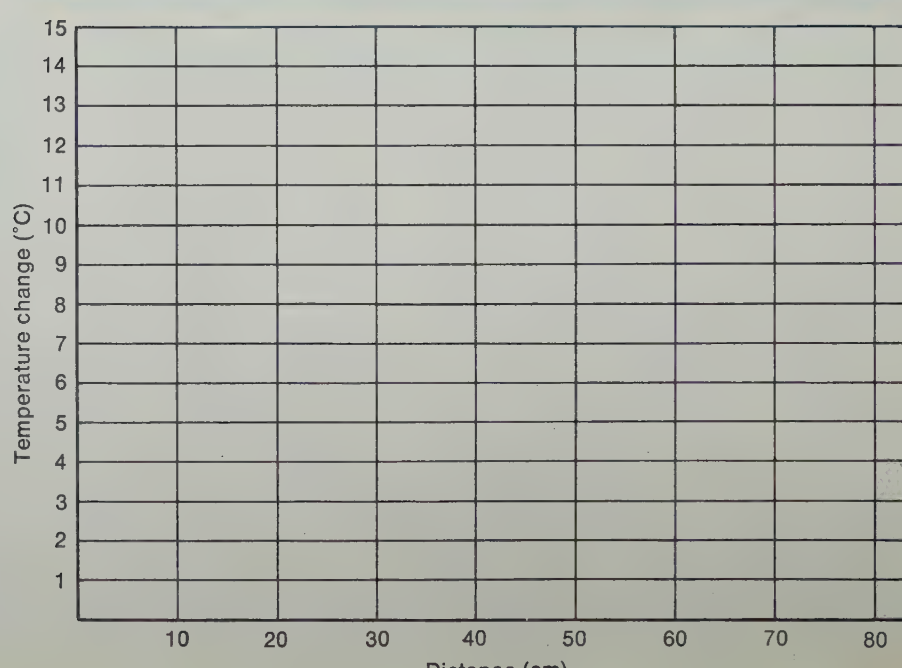
Take temperature readings for each of the distances given in Table 3-1. In each case, turn on the lamp for 3 minutes. At the end of that time, record the total temperature change. Turn the lamp off. Allow the sun-energy measurer to cool off to room temperature. Record all data and make a graph in Figure 3-1 in your Record Book. If you need help with graphing, do **Resource 5,** "Pictures of Relationships."

RESOURCE

Table 3-1

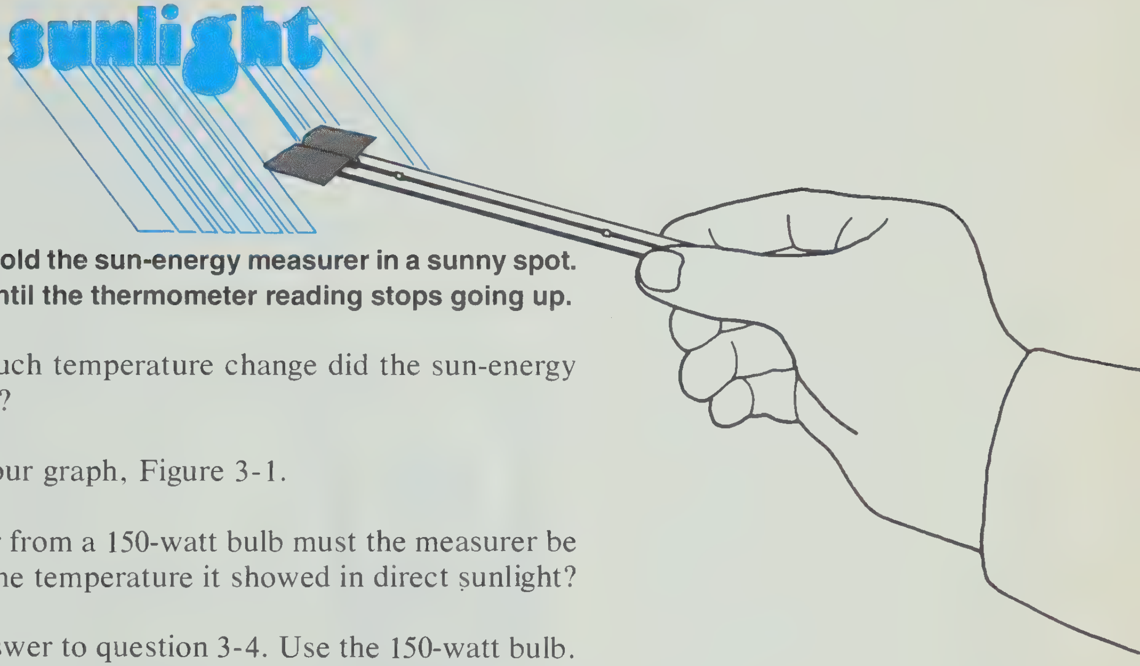
Distance (cm)	Temperature (°C)		Total temperature change (°C)
	Initial	Final	
10			
20			
30			
40			
50			
60			
70			
80			

Figure 3-1



☐ **3-2.** In your experiment, why should you keep the light source constant at 150 watts?

Now let's return to the problem that started Chapter 2. How can you find out how much energy the sun is giving off?



ACTIVITY 3-1. Hold the sun-energy measurer in a sunny spot. Leave it there until the thermometer reading stops going up.

☐ **3-3.** How much temperature change did the sun-energy measurer show?

Now look at your graph, Figure 3-1.

☐ **3-4.** How far from a 150-watt bulb must the measurer be to show the same temperature it showed in direct sunlight?

Test your answer to question 3-4. Use the 150-watt bulb. Place the sun-energy measurer at the distance you gave in question 3-4.

☐ **3-5.** Was your prediction in question 3-4 correct?

Suppose you moved the socket a kilometre from the sun-energy measurer. But you still wanted to have the temperature go up. How many 150-watt bulbs would you need? You'd have to have a huge amount of energy to give the same reading.

The sun is many, many kilometres from the earth. You now know the sun is giving off a huge amount of energy. It produces a big change in temperature in your sun-energy measure. To figure out how much energy, you will need to know how many kilometres away the sun is. The next chapter tells how to measure the distance from the earth to the sun.

Before going on, do Self-Evaluation 3 in your Record Book.

GET IT READY NOW FOR CHAPTER 4

The range finders should be assembled. You will need manila folders or large pieces of cardboard taped in place on the range finders. The students will also need white unlined paper. You will also have to set up a sighting range. See the teacher notes in Chapter 4 for directions.

Far-Out Sun

4

EQUIPMENT LIST

Per student-team

1 range finder (assembled, with manila folder taped to pegboard)
1 sheet of white unlined paper
Tape
Pencil and 1 No. 3 one-hole stopper

CHAPTER EMPHASIS

The student investigates the use of a simple range finder for measuring distances and determines some of the variables and the limitations of the instrument.

Excursion 4-1 is keyed to this chapter.

Measuring the distance to the sun may seem like an impossible job. More than likely, you've always used a ruler or metrestick to measure distances. But that won't work for measuring the distance to the sun.

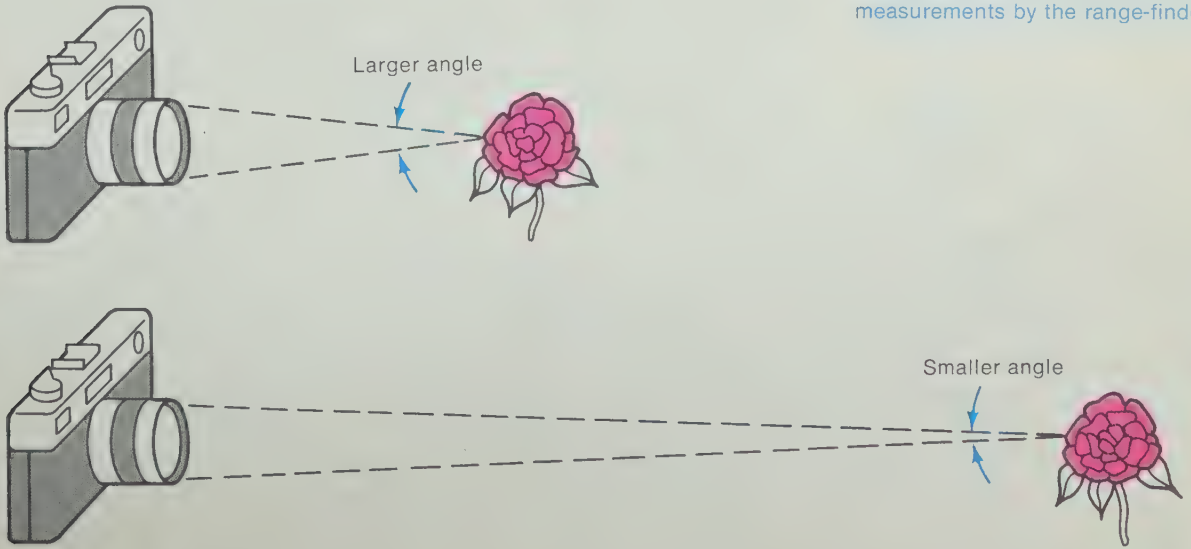
Actually, the problem won't be as difficult as you may think. In many ways, you're like a photographer who wants to know the distance to a moving subject. If the photographer tries to use a ruler or tape measure, there won't be many pictures.

Camera manufacturers have solved this problem. Many cameras include a device called a "range finder." With a range finder, a person looks at the same object from two different positions. The range finder evaluates the distance to the object from the size of the angles formed. (See Figure 4-1.)

MAJOR POINTS

1. The range finder operates on the principle of angles and triangles.
2. A range finder can be calibrated by sighting objects at known distances.
3. As the distance to the object decreases, the angle between the sighting bar and the sighting line increases.
4. As the distance to the object increases, the sighting marks get closer and closer together.
5. The range finder loses its usefulness beyond about 15 metres.
6. The length of the range finder's base line is a limiting factor in the distance that can be measured.
7. In its present form the range finder is useless in measuring large distances, such as the distance to the sun.
8. Another limiting factor of the range finder is its inability to measure the sighting angle accurately.
9. Using any terrestrial distances, the base line is still too short to give accurate angle measurements by the range-finder method.

Figure 4-1

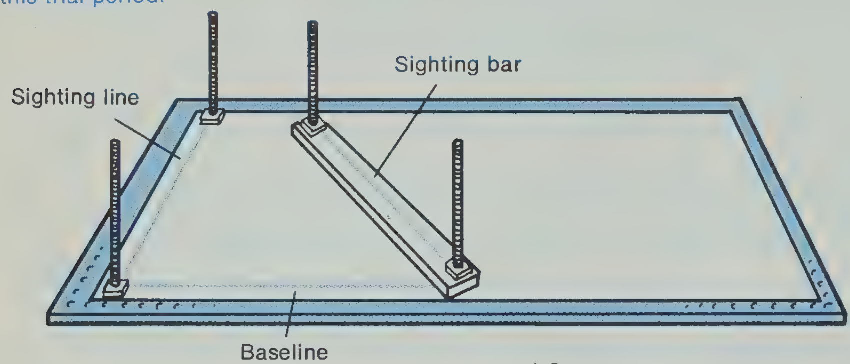


The range finders should be assembled with the manila folder or carboard in place. The white paper should not be added until Activity 4-4, however.

It is important for the students to discover the usefulness and the limitations of the instrument themselves. Resist the temptation to legislate the distances and uses during this trial period.

☐ **4-1.** How does a range finder tell the difference in the distance to the two objects in Figure 4-1?

You can use a simple handmade range finder. It will help you measure the distance to the sun. Get one from the supply area.

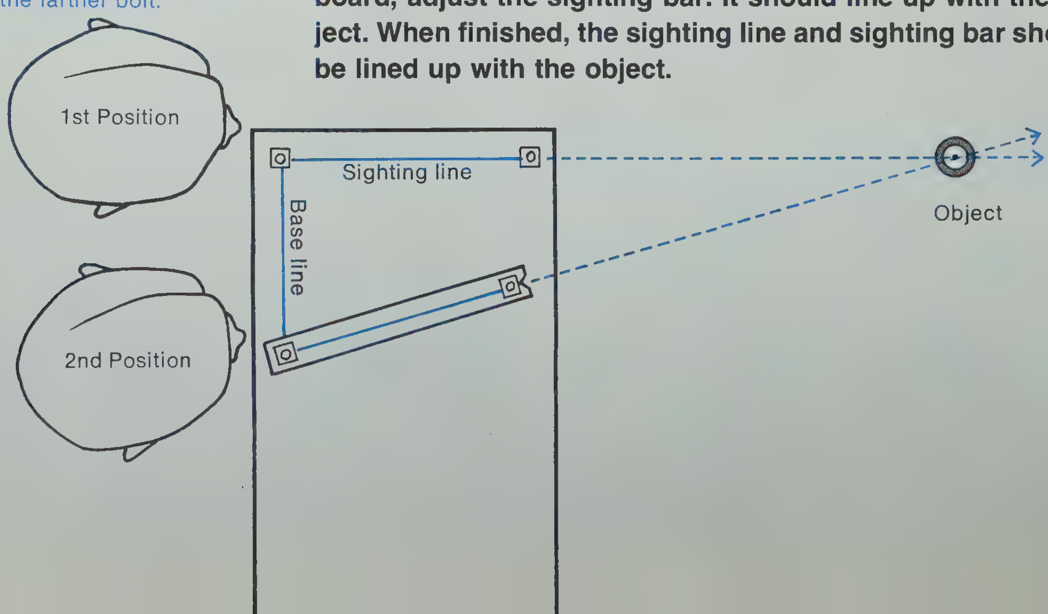


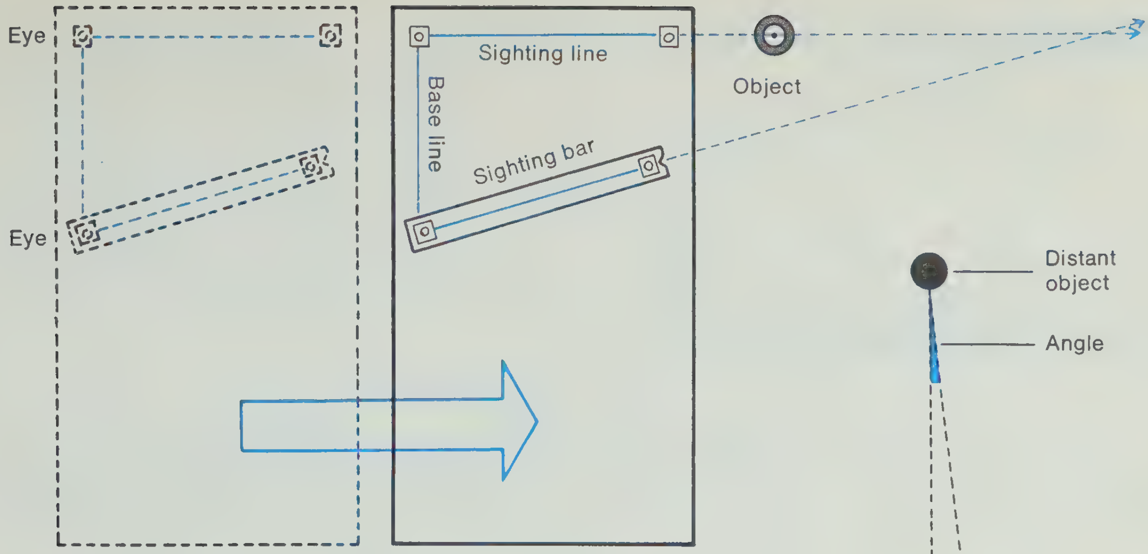
ACTIVITY 4-1. Look the range finder over carefully. Note particularly the labeled parts. If it hasn't been done, draw and label the sighting line and the base line on your range finder.

Before you try to measure the distance to the sun with the range finder, you should learn how it works. Pick out an object to look at on the other side of your classroom. A good object to sight on is a pencil stuck in a one-hole stopper.

In using the range finder, tell the student to keep the sighting eye well back from the bolt. If too close, the nearer bolt completely blocks the sight on the farther bolt.

ACTIVITY 4-2. Place the range finder on a flat surface. Line up the sighting line with the object. Without moving the pegboard, adjust the sighting bar. It should line up with the object. When finished, the sighting line and sighting bar should be lined up with the object.





ACTIVITY 4-3. Move the range finder along the sighting line until it is several feet closer to the object. (See arrow.) *Don't change the position of the sighting bar.*

☐ **4-2.** Does the sighting bar still line up with the object after the range finder is moved? If not, what would you have to do to line it up? Try it!

☐ **4-3.** Suppose you moved the range finder closer to the object along the sighting line. Predict what you would have to do to align the sighting bar.

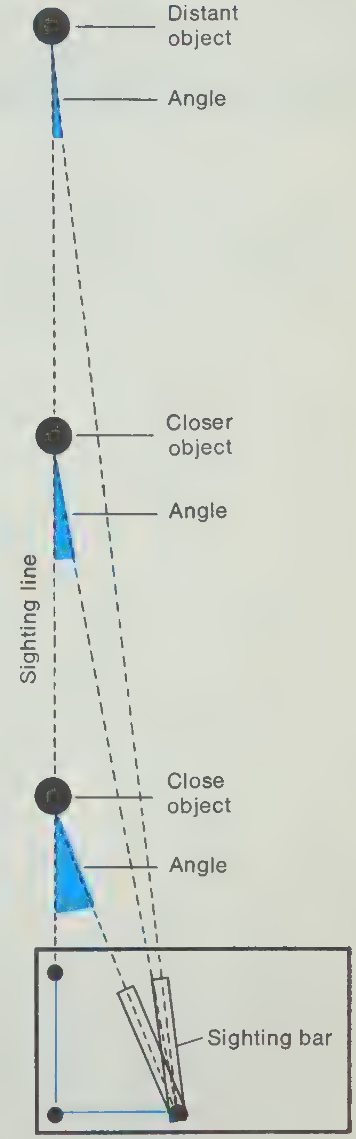
☐ **4-4.** Was your prediction correct?

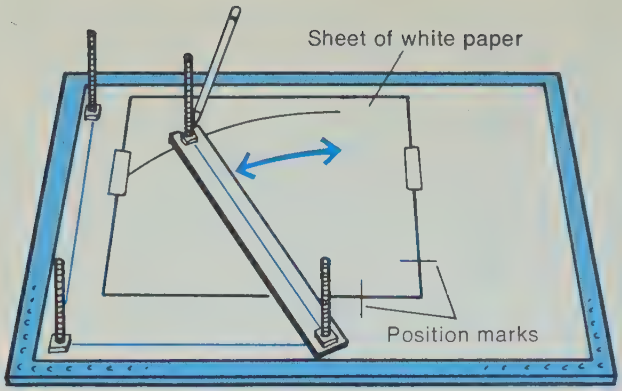
Do you understand the principle of how the range finder works? As the range finder is moved closer to an object, the angle between the sighting bar and the sighting line changes.

☐ **4-5.** Suppose the distance from the range finder to an object increases. How do you predict the angle between the sighting line and sighting bar will change?

Test your prediction in question 4-5 by doing the next activity.

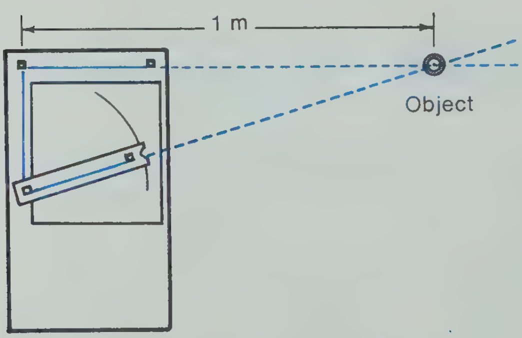
Your teacher has chosen an object and placed marks on the floor at distances from it of 1, 2, 3, 4, 5, 10, and 15 metres.

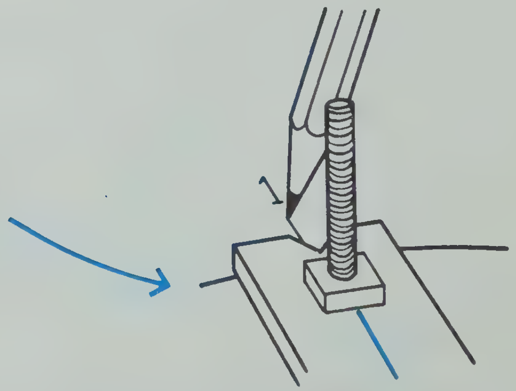




Note that for the calibration of the range finder, beginning with Activity 4-4, you will need a sighting range set up somewhere in the room, with distances of 1,2,3,4,5,10, and 15 metres marked from some object to be sighted. The 15-metre distance (49 feet) is a little large for the average classroom. You may have to stop at a shorter distance, or you might be able to set up the range in a corridor. In the classroom, an excellent sighting object could be a distinct chalk mark on the front chalkboard.

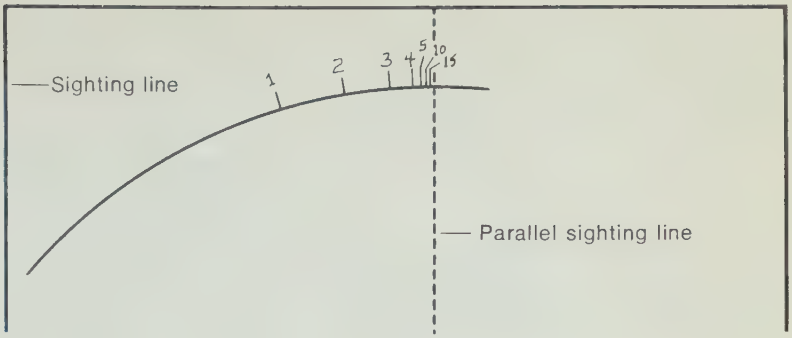
ACTIVITY 4-4. With small pieces of tape, attach a sheet of white paper to the range finder as shown. Hold a pencil in the groove at the end of the sighting bar. Turn the bar to draw a complete arc across the page. Make a mark, or two, on the edge of your paper and the range finder. This will help you position it again if you don't finish today. Be sure to save the paper for later work.





ACTIVITY 4-5. Place the range finder so that the sighting line rear bolt is at the 1-m mark on the floor. Line up the sighting line, and then the sighting bar, with the object. Be sure to sight straight down the bar. The object should look as if it is standing on the far end of the bar. When you are sure the position of the bar is correct, make a mark on the arc as shown. Label the mark "1."

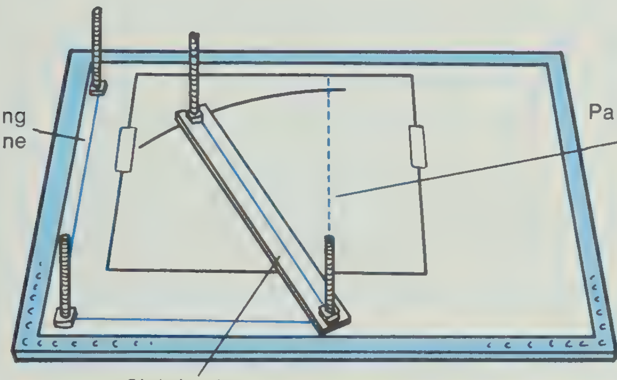
4-6. In question 4-5, the student should have predicted that as the distance gets greater the angle gets smaller. Whatever was predicted, however, the student should now clearly see this important relationship. The decreasing size of the angle and the resulting difficulty of accurate measurement become the limiting factors in the use of the instrument.



ACTIVITY 4-6. Repeat Activity 4-5 for distances of 2 m, 3 m, 4 m, 5 m, 10 m, and 15 m. When your scale is complete, it should appear similar to that shown. Label each mark. The same person should make all the sightings.

The marks and the labeling for 5, 10, and 15 metres will be relatively close together. The numbers will have to be small, and a sharp pencil should be used for making the marks.

Figure 4-2



Practice using your range finder to measure the distance to objects not more than 15 m away. Check your measurements with a metrestick. If they are inaccurate by more than 0.5 m, repeat Activities 4-4, 4-5, and 4-6.

☐ **4-6.** Was your prediction in question 4-5 correct? What happens to the angle formed by the sighting bar and the parallel sighting line shown in Figure 4-2?

☐ **4-7.** Suppose you lined up the sighting line and the sighting bar of the range finder in Figure 4-2 on an object a long way off (like a distant tree). Would you expect the angle between the sighting bar and the parallel sighting line to be large or small?

Check your prediction by using your own range finder. (Draw a parallel sighting line on your range finder if it will help you.)

Select two very distant objects. Have one of these objects farther away than the other. Use the range finder to decide which of the objects is farther away.

4-8. This is a good item to check the student's understanding of the activities. A variety of answers are possible. Hopefully, the student will discover that the motion of the sighting bar is so small that little difference can be seen in the two measurements. This is just another way of saying that the sighting angle is getting too small to measure accurately with the instrument.

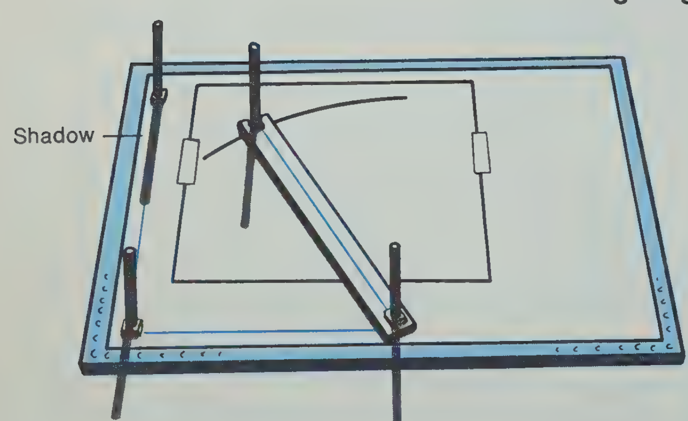
☐ **4-8.** Describe any problems you had in deciding which object was farther away.

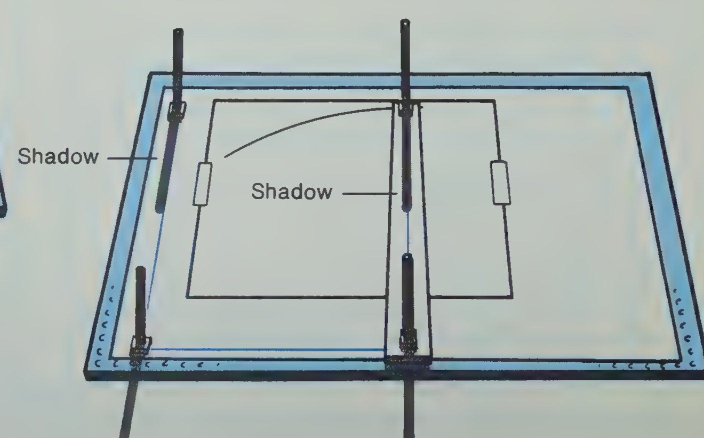
You should have a good understanding of how to use the range finder. It seems to work fine on short distances. But it doesn't work so well for distances beyond 15 m. This may limit its usefulness for measuring great distances such as to the sun. See if it will.

IMPORTANT: Do not allow the students to sight on the sun directly. Even though there is a safety note to the student, a personal word from you might be in order.

Safety Note *Because of the danger of looking at the sun directly, you must change slightly your method of sighting. Instead of lining up bolts, you will try to line up the shadows the bolts cast.*

ACTIVITY 4-7. Set the range finder in a patch of sunlight. Set it up so that the shadow from the front bolt falls directly along the sighting line.





ACTIVITY 4-8. ***Without moving the pegboard,*** **move the sighting bar until the front bolt shadow falls directly along the bar.**

☐ **4-9.** From the position of the sighting bar on your scale, what can you say about the distance to the sun?

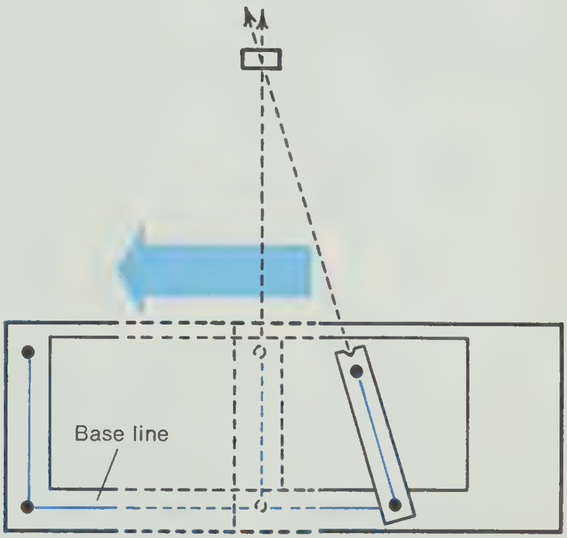
4-9. It is too far away to measure with the range finder. Actually, the sighting bar should be parallel to the sighting line. The angle between two parallel lines (if there is such a thing) is 0°. The angle has simply become too small to measure.

Clearly, you have a problem. There seems to be a limit to the distance you can measure accurately with your range finder.

One variable that limits the distance that can be measured is the length of the range finder's base line.

☐ **4-10.** Suppose you lengthened the base line. How would this affect the greatest distance you can measure with your range finder?

The prediction in question 4-10 should have been that lengthening the base line would increase the greatest distance that could be measured. Actually, the increase would be proportional to the increase in the base line, because the size of the sighting angle is the critical thing, and the tangent of the angle is equal to the base line divided by the distance to the object. Thus, for a given angle, an increase in one factor would make a proportional increase in the other. An experiment to test this prediction might involve shifting the sighting bar on the range finder so that the base line is longer. With the existing configuration, it would be possible to shift the bar so that the base line is twice as long. Measurements could then be made of the effect on the spacing of the marks on the scale. Wider spacing (greater angular change) would be a good indicator of greater distance potential.



PROBLEM BREAK 4-1

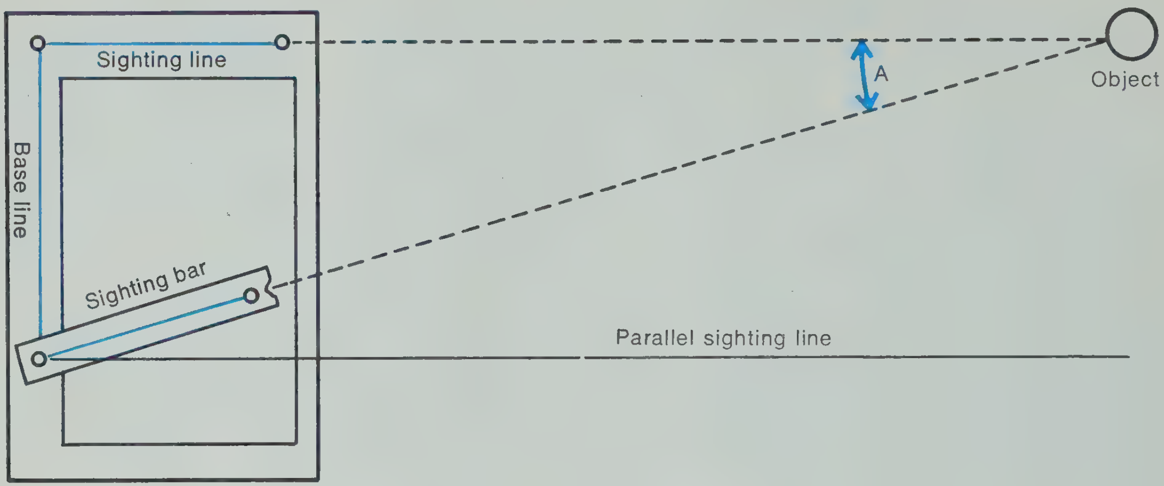
Design an experiment to test what happens when you lengthen the range finder's base line. In your Record Book, describe what you would do and what measurements you would make. Check with your teacher and then do the experiment. Record your results and conclusions.

It should be clear that two variables limit the greatest distance that can be measured by your range finder. The first is the length of the base line. The second is the size of the smallest measureable angle between the sighting bar and the parallel sighting line. This angle is called the sighting angle.

4-11. For a given distance to the object, an increase in the length of the base line increases the size of the angle.

☐ **4-11.** In Figure 4-3, how would increasing the base line affect the size of the angle between the two sighting lines?

Figure 4-3



Now you have a real clue as to how to measure the distance to the sun. Astronomers could make sightings from two observatories that are hundreds or even thousands of miles apart. That would make a really big base line for the two sightings. Figure 4-4 shows how this can be done.

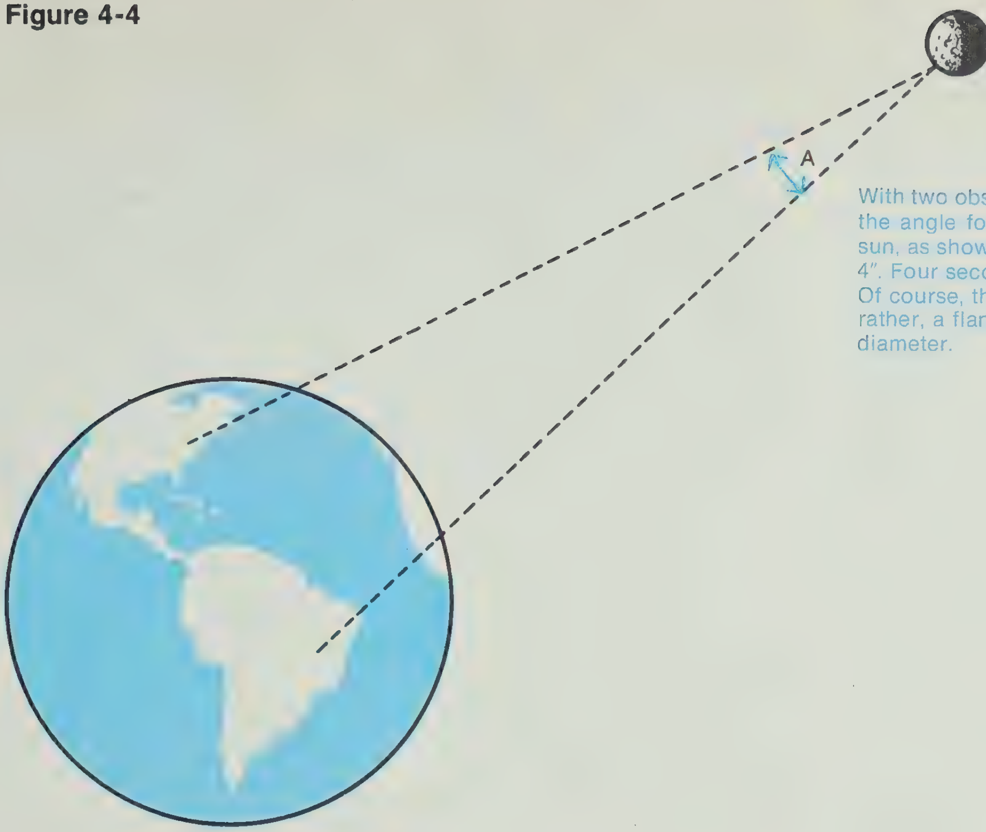
4-12. The angle would increase. For small angles (which these are) the increase would be proportional to the increase in the base line.

☐ **4-12.** If you switched from a simple range finder to the system shown in Figure 4-4, what effect would this change have on angle A?

Modern instruments can measure angles of less than 1/1000 of a degree. To increase the base line, sightings of the sun can be made from widely spaced observatories. But even then, the angle turns out to be too small to measure accurately. Unfortunately, the range finder just can't do the job. You need a much larger base line. In the next chapter, you will search for such a base line.

Meanwhile, you might like to know that the distance to the moon has been measured by the range-finder method.

Figure 4-4



With two observatories about 3200 km apart, the angle formed by a point source on the sun, as shown in Figure 4-4, would be about 4″. Four seconds is close to $\frac{1}{1000}$ of a degree. Of course, the sun is not a point source but, rather, a flaming ball about 1 400 000 km in diameter.

The average distance to the moon is about 385 000 km. Knowing the distance to the moon makes it simple to find the size (diameter) of the moon.

If you would like to measure the diameter of the moon, **Excursion 4-1,** "The Moon's Measurements," will show you a method that is simple. All you need is a full moon, some time to sit still, and a watch.

Before going on, do Self-Evaluation 4 in your Record Book.

EXCURSION

Excursion 4-1 is of general interest. As it requires a full moon, which will not be in the sky during school hours, it should be done at home. And it need not take a great deal of time.

GET IT READY NOW FOR CHAPTER 5

No new equipment need be prepared. The activities call for students to use 3 beans or other small objects on which to sight. Many different things could be used. Large-headed roofing nails stand up well; thumbtacks would do.

Excursion 4-1
The Moon's Measurements

PURPOSE

To show a simple method for measuring the diameter of the moon.

EQUIPMENT LIST

Watch or timer with second hand

This is a general-interest excursion that requires a short period of observation outside of school and a small amount of calculating.

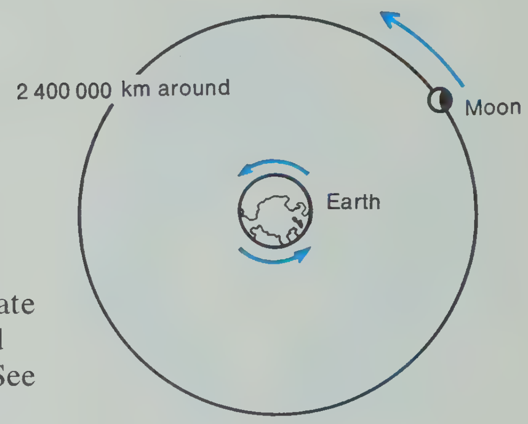
MAJOR POINTS

1. The distance around the moon's orbit, 2 400 000 km can be found by multiplying the distance to the moon, 385 000 km by 2 × 3.14 (2 pi).
2. The apparent motion of the moon is influenced by the rotation of the earth and the movement of the moon in its orbit.
3. Most of the apparent motion of the moon is due to the earth's rotation.
4. The time that it takes for the moon to move one diameter in the sky, divided into the length of time for one day (24 hours), will give the number of moon diameters in one orbit.
5. Dividing the number of km in the moon's orbit (2 400 000 km) by the number of moon diameters in one orbit will give the diameter of the moon in km.

In 1968, the world was thrilled by the successful orbiting of the moon by three American astronauts. These astronauts, Borman, Lovell, and Anders, were in an excellent position to measure the size of the moon.

Even though you are a long way from it, you, too, can measure the moon. And you can do it almost as accurately as the astronauts could. You need a clock and the ability to visualize the motion of the moon with respect to the earth. Figure 1 will help you do this.

Figure 1



How do you calculate the distance around the moon's orbit? See the last part of this excursion.

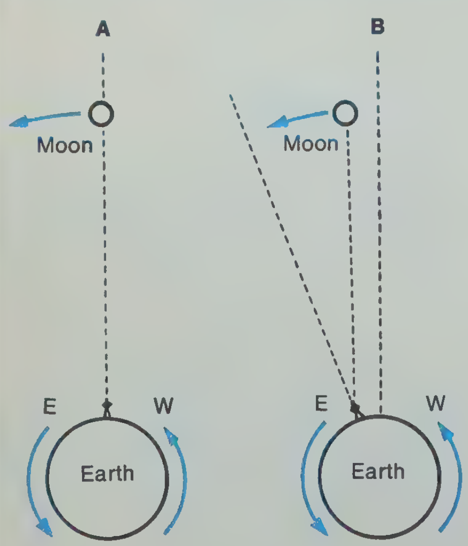
Notice that the figure reminds you of two important assumptions. Keep these in mind as you proceed.

1. It is assumed that the moon's orbit is a circle, 2 400 000 km around. The earth is placed at the center of that circle.
2. The earth turns at a constant speed.

But astronomers have shown that these assumptions are not completely accurate. They are close enough, however, to make the measurements you need.

Choose a night when the moon is full and the weather clear. Watch the moon for a few minutes. Look carefully. You will notice that the moon appears to move in the sky. You may even notice that it moves from east to west. Look at Figure 2 and do some thinking.

Figure 2



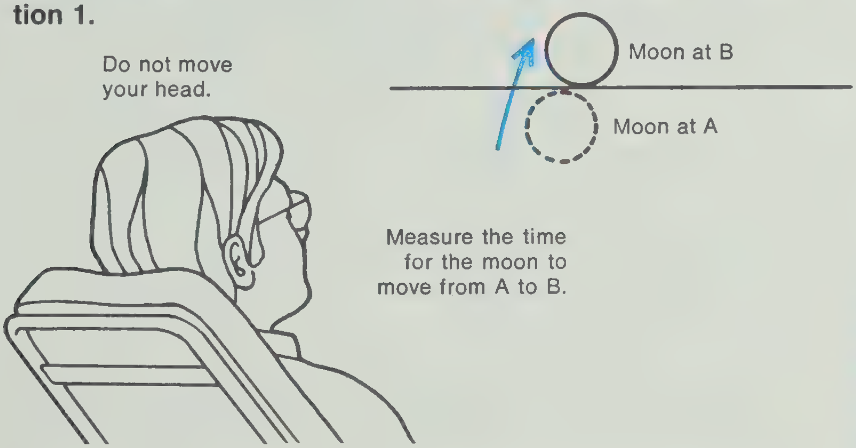
The apparent motion of the moon is influenced by two things: (A) the turning of the earth, and (B) the moon's movement in its orbit.

Most of what appears to be the motion of the moon is due to the turning of the earth. When you view the moon for an hour or so, all the motion observed is due to the earth's turning. Assume this to be so as you make the observation called for in Activity 1.

Your first problem will be to find out how fast the moon appears to move. Since doing this may take an hour or so, start your work fairly early in the evening.

The correct timing of the passage of the moon across a wire is the crucial point. In order to get a reasonable measurement, the wire should be in such a position that it is at a right angle to the moon's orbit so that the moon will pass straight across the wire and not laterally along it. The actual time of passage will be relatively short, but it may take considerably longer to get in the proper position for the sighting.

ACTIVITY 1. Line up the top of the moon with a power line or telephone wire. Rest your head against some object to keep your eye steady. Now time the movement of the moon across the wire. Record the time in minutes as your answer to question 1.

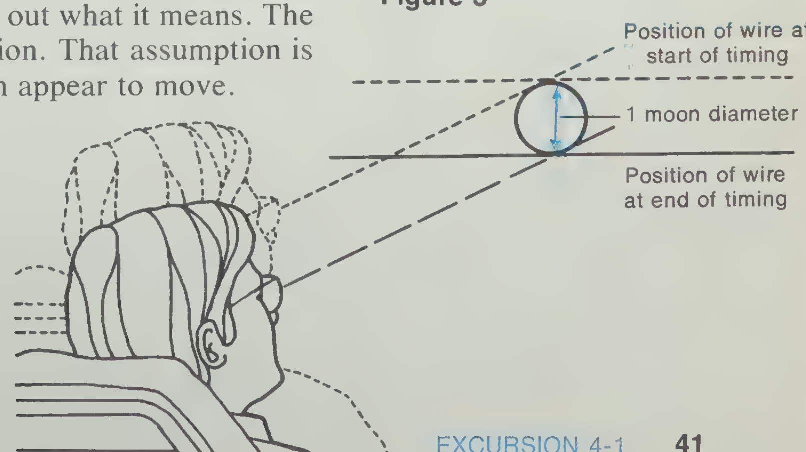


☐ **1.** How many minutes did it take the moon to pass across the wire?

1. The time should be about 2 minutes. For simplicity in the calculations, you may want the students to round off the reading to the nearest minute, and not use a fraction or a decimal of a minute above or below the two minutes. Question 2 is just a reaffirmation of this same reading of 2 minutes. Question 3 is 24 hours per rotation multiplied by 60 minutes per hour, or 1440 minutes per rotation. In question 4, 1440 minutes per rotation divided by 2 minutes per diameter gives 720 diameters per rotation.

Your answer to question 1 is a very interesting measurement. Figure 3 may help you figure out what it means. The drawing is based upon an assumption. That assumption is the earth's motion makes the moon appear to move.

Figure 3



The rotation of the earth moves wire and observer to a new position with respect to the moon. Since observers think themselves motionless, they naturally believe the moon has moved.

☐ **2.** In question 1, you recorded the minutes it takes for the wire to sweep across one moon diameter. How many minutes did this sweep take?

☐ **3.** How many minutes does it take the earth to make one complete rotation?

☐ **4.** How many moon diameters would a telephone wire sweep across in one full day? (Hint: You know the time needed to sweep across one moon diameter. You also know how many minutes there are in one full day.)

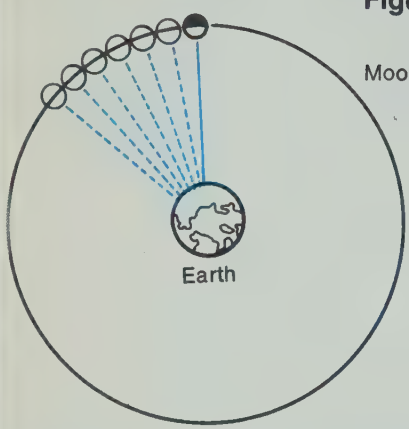
You now have enough information to calculate the moon's diameter. Your answer to question 4 tells you how many moon diameters there are in one moon orbit. Figure 4 illustrates this.

You also know the length in miles of the moon's orbit (2 400 000 km). The following relationship allows you to make the final calculation.

$$\text{Diameter of moon (km)} = \frac{\text{Length of moon's orbit (km)}}{\text{Number of moon diameters in one orbit}}$$

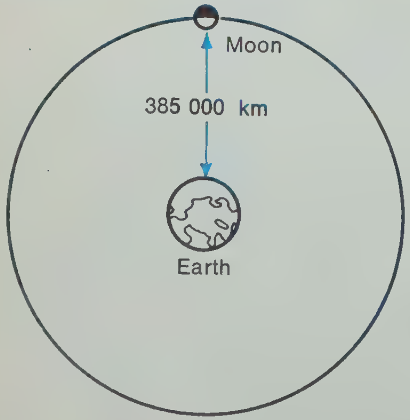
☐ **5.** What is the diameter of the moon?

Figure 4



5. The calculation should show 2 400 000 km per rotation divided by 720 diameters per rotation, or about 3330 km for the diameter. The accepted astronomical figure is 3456 km, which means that the student measurement is smaller by less than 4%. This could be considered a remarkably accurate accomplishment.

Figure 5



SPECIAL NOTE TO STUDENTS ON CALCULATING THE LENGTH OF THE MOON'S ORBIT

Are you wondering how the moon's orbit was measured? In Chapter 4 you learned that the moon is about 385 000 km from the earth (Figure 5).

You may know that the distance around any circle (circumference) may be found by multiplying the distance across the circle, through its center (diameter) by a constant called π (pronounced "pie"). The value of π is approximately $\frac{22}{7}$, or 3.14. With this in mind:

$$\begin{aligned} \text{Distance around} &= \pi \times \text{distance across} \\ &= \pi \times 2 \times \text{half the distance across} \\ &= 3.14 \times 2 \times \text{half the distance across} \\ &= 6.28 \times \text{half the distance across} \end{aligned}$$

In Figure 5, "half the distance across" the circle is the distance from the earth to the moon. Thus we write:

$$\begin{aligned} \text{Length of the moon's orbit} & \\ &= 6.28 \times \text{distance from the earth to the moon} \\ &= 6.28 \times 385\ 000 \text{ km} \\ &= 2\ 400\ 000 \text{ km} \end{aligned}$$

An astronomical oddity is the fact that, seen from the earth, both the moon and the sun measure about $\frac{1}{2}°$ in the sky. This is about the width of a pencil held at arm's length. It is because of this odd fact that the moon can exactly eclipse the sun at times when they line up in the heavens. This also gives an alternative method for doing the problem. If the earth rotates on its axis through 360° in 24 hours, then it rotates 15° per hour. That is 15 divided by 60, or $\frac{1}{4}°$ per minute. To go $\frac{1}{2}°$, then, would require 2 minutes, which is the time the student should have observed. Dividing $\frac{1}{2}°$ per 2 minutes by 360° per rotation gives $\frac{1}{720}$ of a rotation in 2 minutes. $\frac{1}{720}$ of the orbital distance of 2 400 000 km is the same 3330 km.

CHAPTER EMPHASIS

Starting with the distance from Earth to Venus as a base line, the range-finder method can be used to find the distance to the sun.

Measuring the Distance to the Sun

5

FILMSTRIP KEY
(Enrichment)
How Far Is That Star?

Excursions 5-1, 5-2, 5-3, and Resource 9 are keyed to this chapter.

Excursion 5-1 is a short general-interest exercise requiring no equipment. It is titled "What's Radar?"

EQUIPMENT LIST

Per student-team

1 protractor
1 drawing compass
Map pins
1 metric ruler
Cardboard to place drawing on

MAJOR POINTS

1. The sun is the center of the solar system.
2. Venus and Earth are planets in the solar system and move in nearly circular orbits in the same plane around the sun.
3. The Venus orbit is within the Earth orbit.
4. The angular speed of Venus is greater than that of Earth: therefore, Venus and Earth are constantly changing relative positions.
5. The angle between the lines of sight to two bodies is called the sighting angle.
6. The largest angle between the Earth-Venus line and the Earth-sun line occurs when the Earth-Venus line just touches the orbit of Venus.

EXCURSION

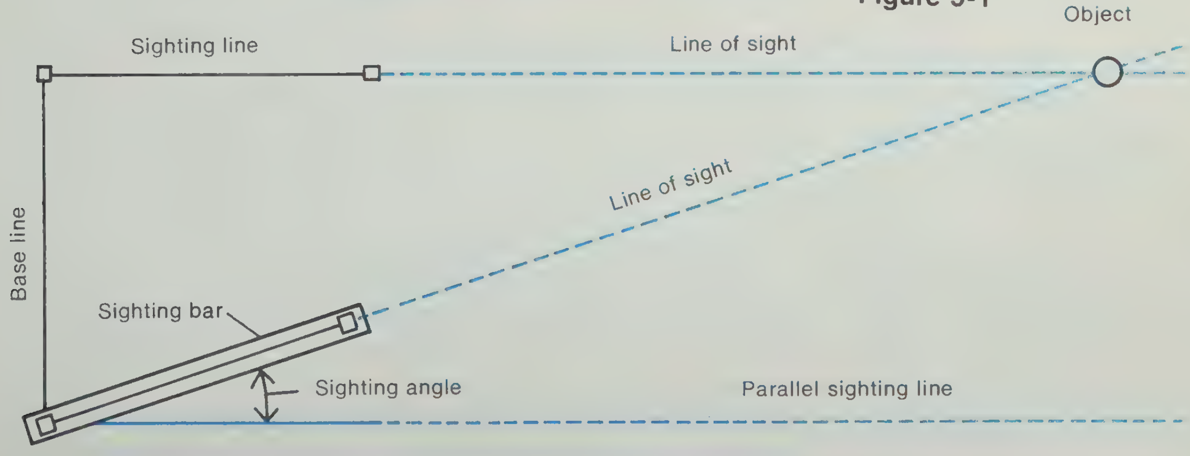
7. Using the largest sighting angle, the orbit of Venus and the orbit of Earth can be drawn to scale.
8. Knowing the minimum distance from Earth to Venus, the distance from Earth to the sun can be calculated from the scale drawing.

Years ago, scientists discovered an interesting way to locate objects at a distance. They used radar. Using radar, they could measure the distance to the moon and to some of the planets. They found, for example, that Venus, when closest to Earth, is about 42 million km away. If you are interested in information about using radar to measure distances, see **Excursion 5-1,** "What's Radar?" It explains why radar isn't used to measure the distance to the sun.

The measurement of the distance to Venus has proved useful. This distance can be used in determining how far the sun is from Earth. Let's see how.

9. The distance to the sun is about 149 million km.

Figure 5-1



☐ **5-1.** How could the distance from Earth to Venus be used in measuring the distance to the sun?

Question 5-1 is a difficult question. If the student suggests the distance might be used as a large base line, that is an excellent answer. The purpose of the question is to encourage reading of the lead information, which focuses on the problem in the chapter.

Figure 5-1 shows how the range finder used in the last chapter works. Take a close look at the figure. Then answer question 5-2.

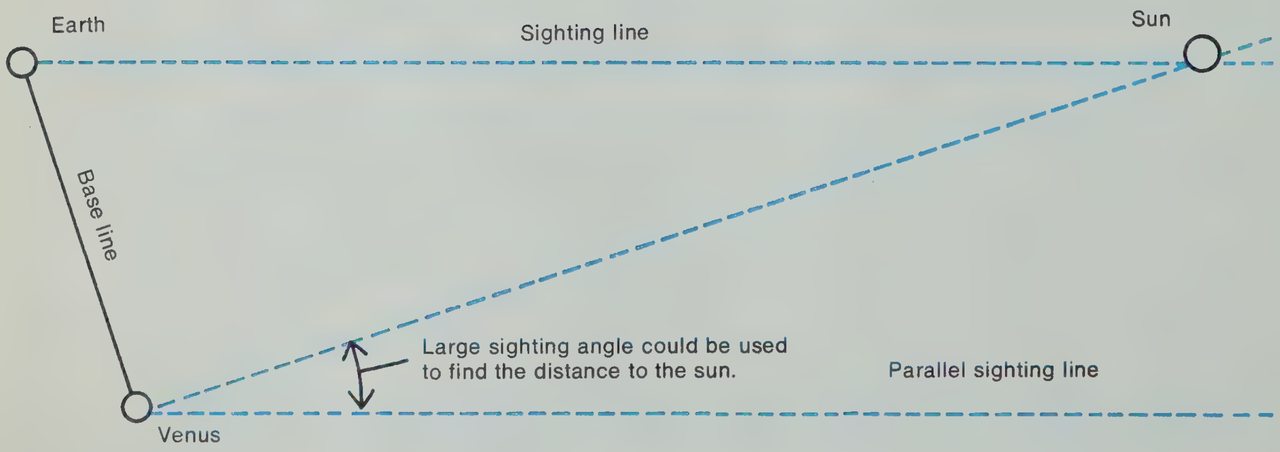
5-2. The base line is too short; thus the sighting angle is too small to measure.

☐ **5-2.** Why can't the range finder you used in Chapter 4 measure large distances?

The distance across Earth is too small a base line for the range-finder method to be used to measure the distance to the sun. But suppose the distance from Earth to Venus could be used as a base line (Figure 5-2).

☐ **5-3.** What problems would there be in using the scheme in Figure 5-2?

Figure 5-2



Notice that in Figure 5-2, the base line is not perpendicular to the sighting line from Earth to the sun. This may confuse some students. You may have to point out that it is not necessary for it to be perpendicular, and the method still works as long as the sighting line and the parallel sighting line are parallel.

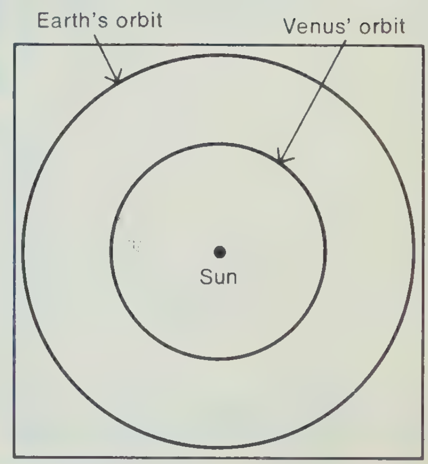
Obviously, you can't easily get to Venus to make a sighting of the sun. This alone seems to make the plan shown in Figure 5-2 impossible. But there is another way to use the distance between Earth and Venus. You must first work with a model of the position of Venus in relation to Earth and the sun. Column 2 of Table 5-1 and the activities that follow will help you do this. Column 1 lists the basic facts used in making the model.

RESOURCE

Do you know what a model is? If not, do **Resource 12,** "Model Building," before going on.

Table 5-1

Basic facts	Effect on drawing of model
1. The sun is the center of the solar system.	1. Sun is shown as center of drawing.
2. Earth and Venus are planets revolving around the sun.	2. Venus and Earth are shown as moving around the center (sun).
3. Venus and Earth move in the same plane.	3. Both Earth and Venus can be drawn on flat paper.
4. Both Venus and Earth move in roughly circular paths (orbits).	4. Orbits are shown as circles.
5. Venus is closer to the sun than Earth is.	5. Venus's orbit is drawn smaller than Earth's orbit.



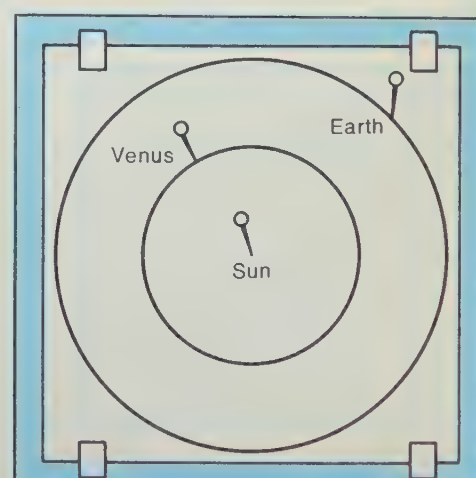
Questions 5-4 through 5-7 relate to Table 5-1.

☐ **5-4.** Why is the sun placed at the center of the drawing?

☐ **5-5.** What does "in the same plane" mean?

☐ **5-6.** Why are the orbits of Venus and Earth represented by circles in your drawing?

☐ **5-7.** Why is the circle for Venus's orbit smaller than the circle for Earth's orbit?



ACTIVITY 5-1. Remove the page with the circles on it from your Record Book. Then label the sun.

ACTIVITY 5-2. Place a map pin anywhere on the line of each of the two circles. These will represent Earth and Venus. Place another pin in the center of the circles to represent the sun. You may want to use different-colored pins. Use cardboard backing under the circles to hold the pins. Tape the drawing to the cardboard.

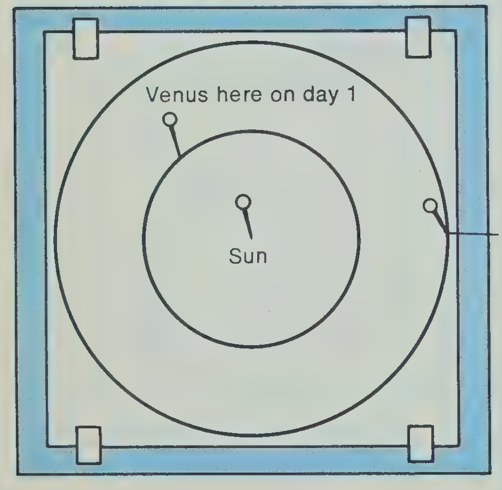
Now use your model—the pins and circles—to study the motions of Venus and Earth with respect to each other. To do this you will have to add two more facts to your list.

1. Earth travels completely around its orbit once every 365.25 days.
2. Venus takes 225 days to make one complete orbit around the sun.

5-8. Venus travels around the sun 365/225 times as fast as Earth does. This is 1.62 times as fast. Figure 5-3 should show Earth back in the same position from which it started and Venus making about 1.6 revolutions from its starting point.

☐ **5-8.** Suppose the planet Earth made a complete orbit around the sun. During that time, would Venus have made more or less than one orbit around the sun? (Answer by drawing the approximate position of Venus in Figure 5-3 in your Record Book.)

Figure 5-3

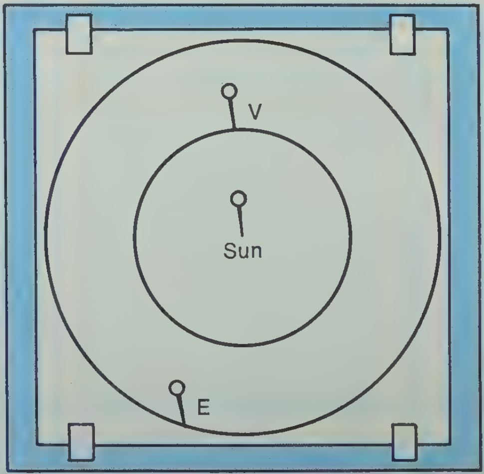


☐ **5-9.** Does Venus travel faster, or slower, than Earth as it moves around the sun?

5-9. Faster. The more obvious reference is to angular speed. It travels one revolution (360°) in 225 days while Earth requires more than 365 days to revolve around the sun. Not so obvious, and not important for the student to know, is the fact that, being closer to the sun, Venus also travels at a faster linear speed by about 20%. Thus it not only has a shorter distance to go for one revolution, but travels the distance at a faster rate as well.

Astronomers have known for many years that Venus's orbit is within Earth's orbit, because Venus is always seen as a morning or an evening "star." It never gets farther than about 46° from the sun and is never seen late at night, as are Mars and Jupiter.

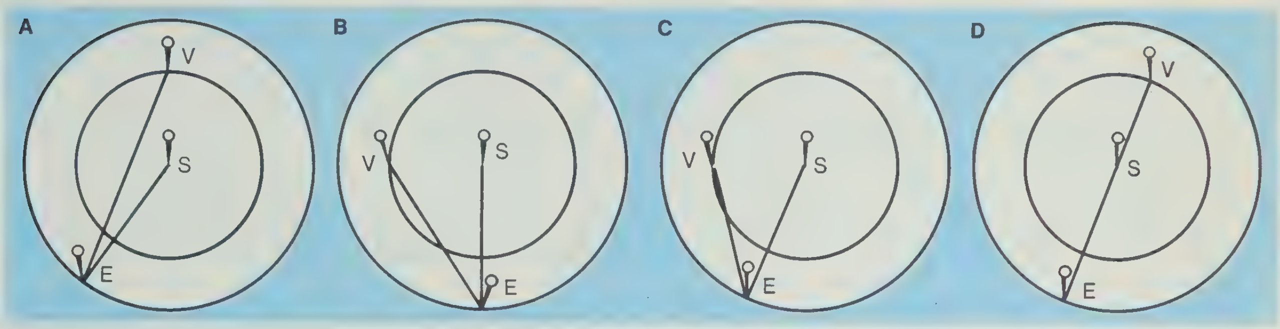
The last activity gives an idea of the paths and movement of Venus and Earth. You are to visualize what the motion of Venus would look like from Earth. Once again, your model can help.



ACTIVITY 5-3. Arrange the pins as shown.

Move the Earth and Venus pins to other points along their circular orbits. Notice that the three pins always form a triangle (except when they are lined up). See Figure 5-4.

Figure 5-4

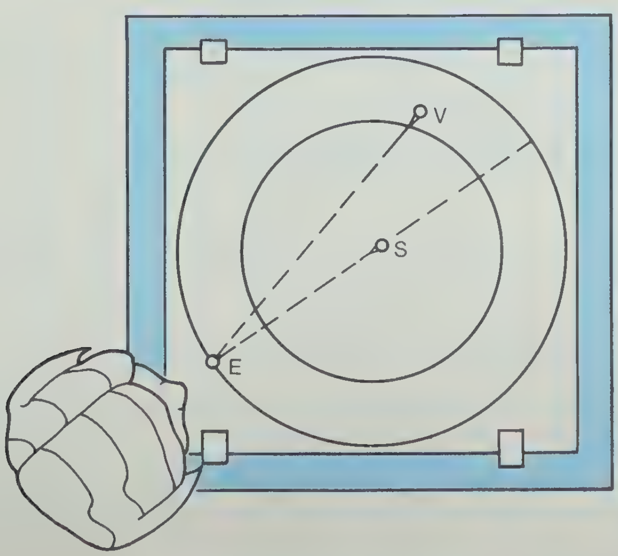


☐ **5-10.** In Figure 5-4, which drawing shows the pins not in a triangle?

Imagine yourself standing on Earth looking at Venus and the sun. Activity 5-4 will help you visualize this.

ACTIVITY 5-4. Look at eye level from behind the pin representing Earth along the paper toward the sun. Then repeat from Earth toward Venus. The pins should be arranged as in Activity 5-3.

This sighting of the anlge between the two lines formed by the pins (or other objects) is somewhat difficult, but important. You may have to provide help to some students.



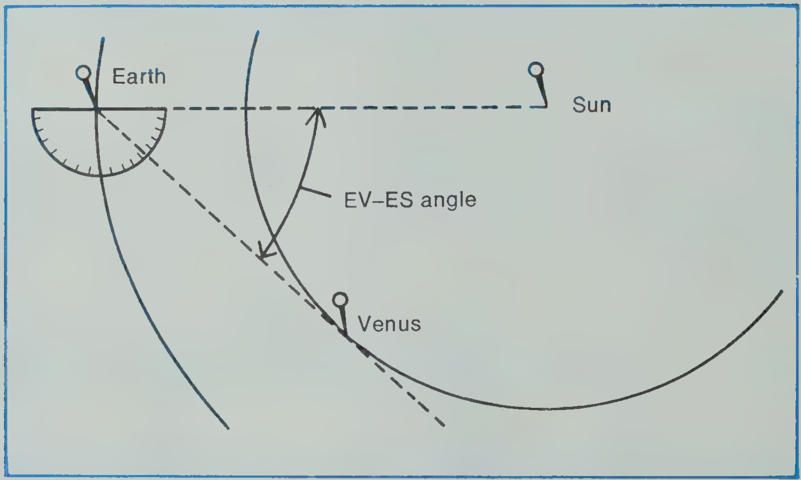
☐ **5-11.** In Activity 5-4, what measurement could be made to describe the position of Venus with respect to the sun and Earth?

Question 5-11 is not easy. The answer is "the angle formed by line EV (the line of sight from Earth to Venus) and line ES (the line of sight from Earth to the sun)." This angle can be used to describe the position of Venus with respect to the sun and Earth.

☐ **5-12.** As Venus and Earth move in orbit, what two things happen to the angle formed by EV and ES?

Resource 9 provides help on the use of a protractor. Protractors differ, and the student may need practice on the particular kind that is available, even though one might have been used previously.

ACTIVITY 5-5. Experiment by moving Earth and Venus until you find the position at which the EV-ES angle is greatest. Measure this angle with a protractor. (See *Resource 9*, "Measuring Angles," if you don't know how to use a protractor.)



☐ **5-13.** When is the EV-ES angle greatest?

☐ **5-14.** What number of degrees are there in the greatest possible EV-ES angle?

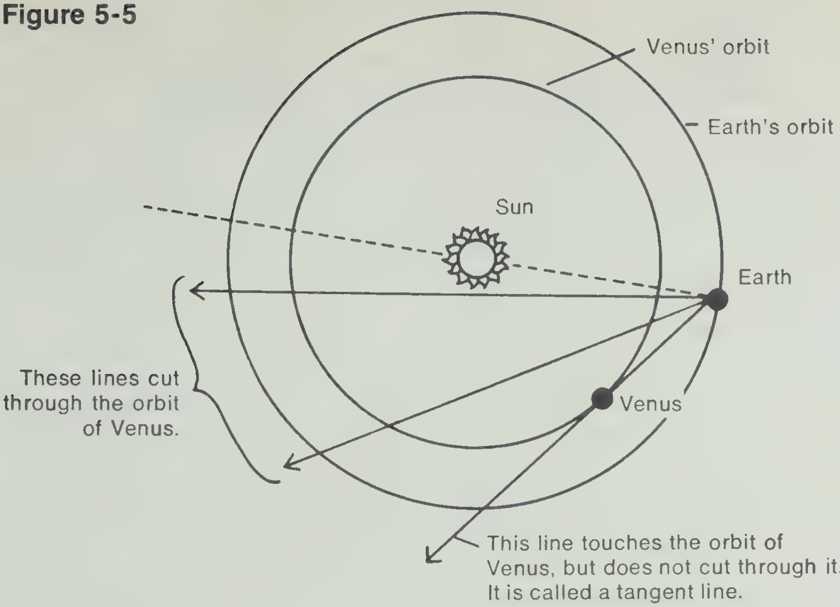
☐ **5-15.** When is the EV-ES angle smallest?

The number of degrees in question 5-14 may vary, but this is not important. More important is the concept in question 5-13: that the angle will be greatest when the line of sight to Venus just touches the orbit circle. Of course, the angle will be smallest (0°) when the sun, Earth, and Venus are in a straight line.

Check your answers to questions 5-13 through 5-15 by examining Figure 5-4 again.

The greatest EV-ES angle occurs when the line of sight from Earth to Venus just touches, but does not cut, the orbit of Venus. (See Figure 5-5.)

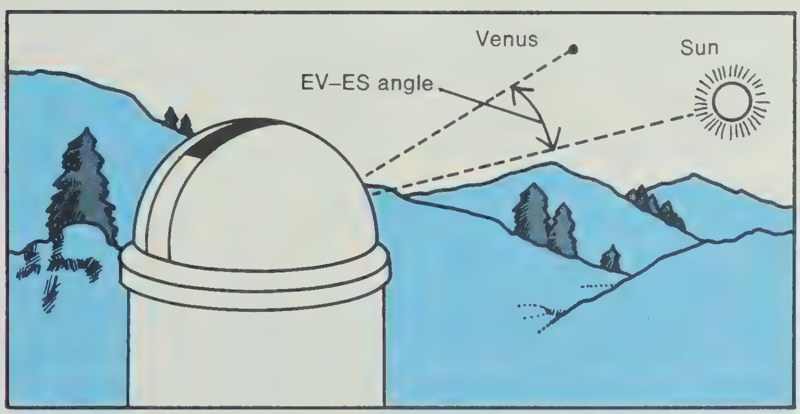
Figure 5-5



The orbits of Earth and Venus are not perfect circles but, rather, slightly elliptical. This means that there are points on the Earth orbit where sightings to the Venus orbit can vary by a number of degrees. For instance, if the sighting is made when Earth is farthest out on its ellipse and Venus is closest to the sun on its ellipse, the angle will be smaller than if Earth is closest to the sun and Venus has swung out to its greatest distance. But using circular orbits of the average distances to the sun as the student is doing, the greatest angle is about 46°.

From this point on in the chapter, drawings will be made to scale and angles measured accurately. The success of the distance measurements to the sun depends on these accurate measurements.

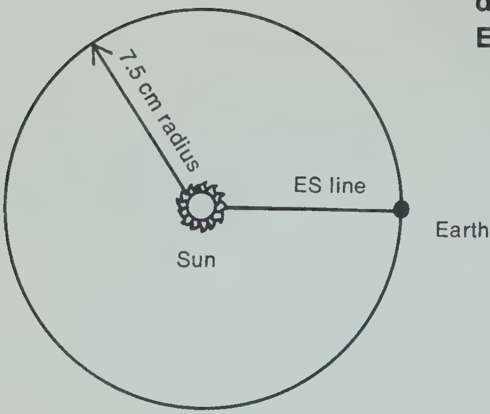
Figure 5-6



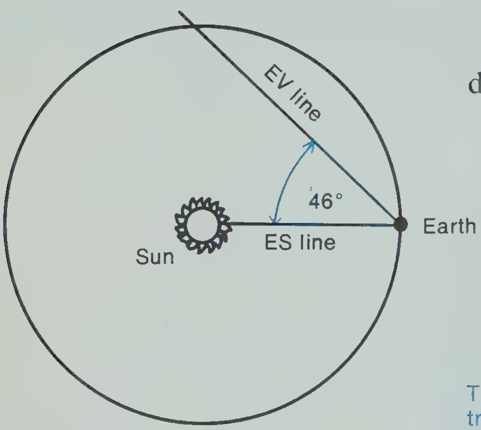
Measuring the real EV-ES angle is easy for astronomers (see Figure 5-6). They have found that the greatest EV-ES angle averages 46°.

What does this have to do with how the distance from Earth to the sun is measured? That was the question that started this discussion of EV-ES angles.

☐ **5-16.** What is the largest average Sun–Earth–Venus angle astronomers have measured?



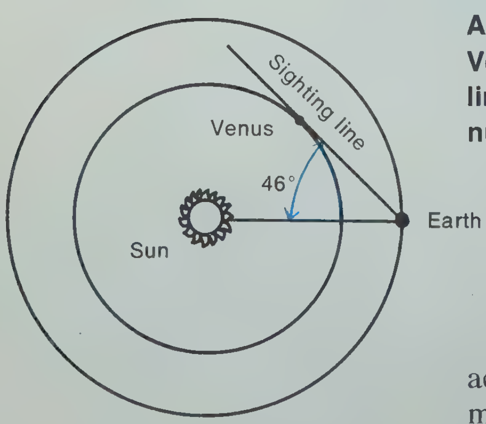
ACTIVITY 5-6. In the space provided in your Record Book, draw a circle with a 7.5-cm radius to represent the orbit of Earth. Draw in an Earth-Sun (ES) line as shown.



ACTIVITY 5-7. Using your protractor, draw in the Earth-Venus (EV) line for the largest EV–ES angle (46°).

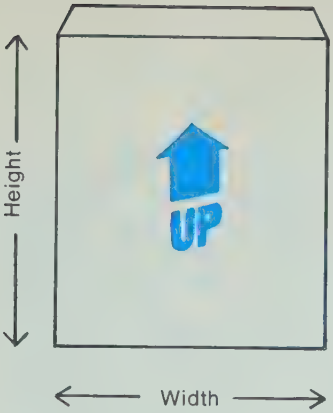
At this largest angle, the orbit of Venus just touches and does not cut this EV line.

The location of the "Venus" dot may be tricky. Geometrically, it is on the perpendicular from the sun to the EV line.



ACTIVITY 5-8. Using a compass, draw the orbit circle for Venus. Remember, the circle should *just touch* the sighting line. At the exact point where the sighting line touches Venus's orbit, make a small dot and label it "Venus."

The drawing you just made is a *scale drawing* of the actual orbits of Venus and Earth. It can be used to determine the distance from Earth to the sun. Before you do this, be sure you know what a scale drawing is by doing the checkup.



Scale: 1 cm = 1 m

CHECKUP 5-1

Excursion 5-2, keyed by the Checkup, is remedial on the use of scale drawings.

Here is a scale drawing of a packing crate.

1. How high (in metres) was the crate from which the scale drawing was made?
2. How wide (in metres) was the actual crate?

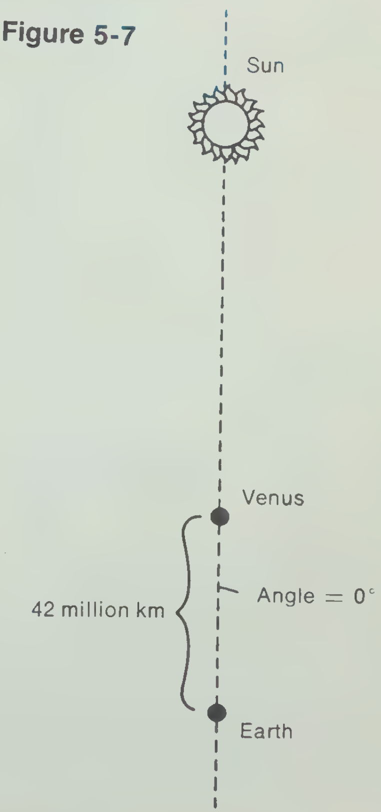
Check your answers to this Checkup on page 57 of **Excursion 5-2.**, "Scale Drawings."

EXCURSION

5-17. This distance should be about 21 mm.

☐ **5-17.** Measure on your scale drawing from Activity 5-8 the distance between Earth and Venus when they are closest together. This will be when Earth, Venus, and the sun are lined up. Also Earth and Venus are on the same side of the sun. See Figure 5-7.

Figure 5-7



☐ **5-18.** What is the distance in mm between E and V on your scale drawing?

The distance you just measured in millimetres represents 42 million km (see Table 5-2). This is the actual distance from Earth to Venus when they are closest.

☐ **5-19.** By your scale, how many km are represented by each mm?

5-19. Each mm represents about 2 000 000 km (42 000 000 ÷ 21 = 2 000 000).

Check your answer:

1. Did you divide 42 000 000 by your answer to question 5-18?
2. Did your answer to 5-19 look *close* to this: 1mm = 2 000 000?
3. If your answer to either 1 or 2 is no, check further with your teacher.

Record your answer to question 5-17 in Table 5-2.

Table 5-2

	On scale drawing (mm)	Actual (km)
Distance from Venus to the sun		
Distance from Earth to the sun		
Smallest distance between Earth and Venus		42 million

5-20. Venus to the sun: about 54 mm, which equals 108 million km at the scale determined in questions 5-17 and 5-19. Earth to the sun: 75 mm, which gives 150 million km at the same scale.

☐ **5-20.** Using your scale drawing, measure (in millimetres) the distance from Venus to the sun. Then measure the distance from Earth to the sun. Record your measurements in Table 5-2.

You now have enough information to complete the problem you started at the beginning of Chapter 5. Just use the data in Table 5-2 and your scale. You can calculate the distance of the sun from Earth. You can also calculate the distance of the sun from Venus.

☐ **5-21.** Using your scale of 1 mm = 2 000 000 km, calculate the distance in km from Venus to the sun and from Earth to the sun. Record the results of your calculations in Table 5-2.

Excursion 5-3 is a remedial excursion for those having calculating troubles.

EXCURSION

A good check on your work is to see if the sum of your actual Venus-to-sun distance and Earth-to-Venus distance equals the Earth-to-sun distance. If the calculations of question 5-21 proved difficult, **Excursion 5-3,** "Practice in Using Scale Drawings," will help you.

You should now have the information you set out to find at the beginning of Chapter 4. You now know a way to calculate the distance from Earth to the sun. Astronomers have found the average distance from Earth to the sun to be roughly 149 million km. Do your results agree?

GET IT READY NOW FOR CHAPTER 6

There are several items that must be supplied locally. These include pieces of cardboard 4 cm square and pieces 13 cm by 20 cm. The cardboard backs from used tablets will do very well. You will also need single-edged razor blades, scissors, and a needle or other sharp instrument for making a small round hole.

Before going on, do Self-Evaluation 5 in your Record Book.

Excursion 5-1
What's Radar?

EQUIPMENT

None

PURPOSE

To explain how radar is used for the measurement of astronomical distances.

This is a general-interest excursion, with practice in using distance calculations.

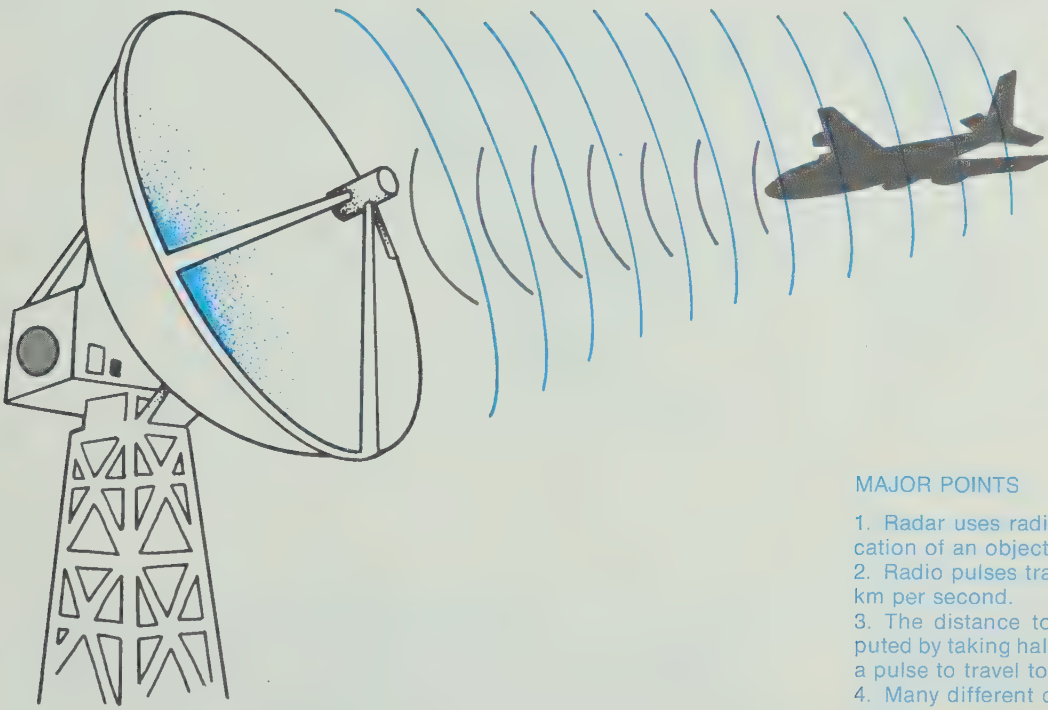
MAJOR POINTS

1. Radar uses radio pulses to detect the location of an object.
2. Radio pulses travel at a speed of 300 000 km per second.
3. The distance to an object can be computed by taking half of the round-trip time for a pulse to travel to the object and back.
4. Many different objects can be located by radar.
5. Radar is ineffective in accurately measuring the distance to the sun.

What is radar? The name *radar* was coined from the words *RA*dio *D*etection *A*nd *R*anging by two United States naval officers, F. R. Furth and S. M. Tucker. Radar is the process of using radio pulses to locate an object. In the process, very short powerful pulses of radio energy are transmitted. They bounce off the object and return to the sending station a bit weaker.

Radar technicians measure how long it takes for a pulse to travel to an object and back. The longer it takes the pulse to return, the farther away the object.

Thus, the time of travel of the pulse determines the distance a target is from the radar set.



This is precisely how radar was used to measure the distance to Venus. Radio pulses travel at 300 000 km/sec. A pulse of energy was beamed at Venus. Then the radar operator waited until the antenna received the reflected signal. Since the round-trip time was about 280 seconds, the one-way trip took half this time; that is, the pulse required 140 seconds, or 2.33 minutes, to travel from Earth to Venus (Figure 1).

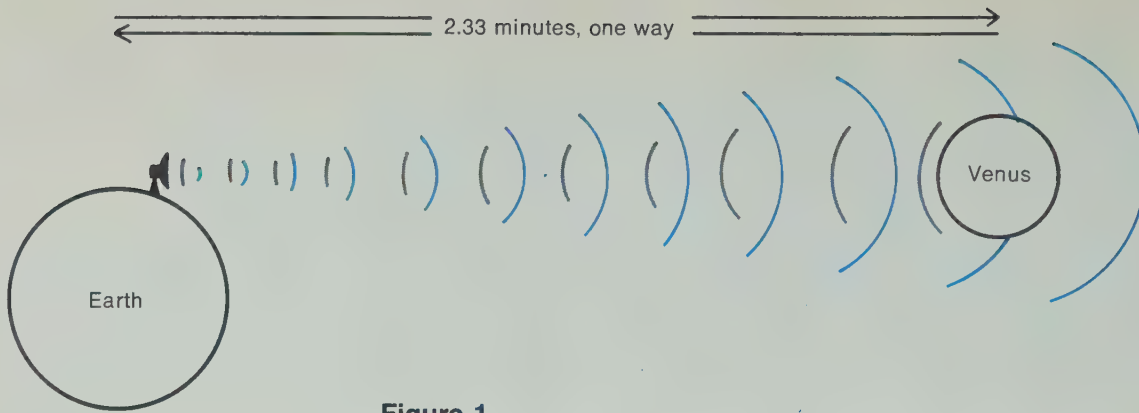


Figure 1

The student may recognize 300 000 km per second as the speed of light and, in fact, of all electromagnetic radiation. Note that the 280-second round-trip time is for the situation when Venus is closest to Earth, and when Earth, Venus, and the sun are in a straight line.

The student may not know how to use speed and time to find distance, and may need help. Speed × time = distance. The answers to the three questions are as follows:

1. 300 000 km/sec × 60 sec/min = 18 000 000 km/min
2. 18 000 000 km/min × 2.33 min = 41 940 000 km
3. Same as 2 (42 million km)

You probably know how to use speed and time measurements to find the distance traveled.

☐ **1.** How far will a radio pulse travel in 1 minute if it moves 300 000 km/sec?

☐ **2.** The pulse takes 2.33 minutes to travel from Venus to Earth. How far has the pulse traveled?

☐ **3.** How far is Venus from Earth?

Using the methods discussed above, radar locates airplanes, ships, birds, thunderstorms, artificial satellites, and planets. The same principle has also been used to measure the distance to Mars, Mercury, and of course to our moon.

So far, scientists have not been able to use radar to accurately measure the distance to the sun. Being a body composed mainly of hot gases, the sun is what scientists call a "soft" target. (A hard target would be a planet.) Therefore, radar can give the distance to Venus to use as a base line in measuring the distance to the sun. But it cannot accurately give the distance to the sun.

Excursion 5-2
Scale Drawings

EQUIPMENT LIST

Metric ruler

PURPOSE

To acquaint the student with the use of scale drawings.

This is a remedial excursion that students should do if they do poorly on the Checkup.

MAJOR POINTS

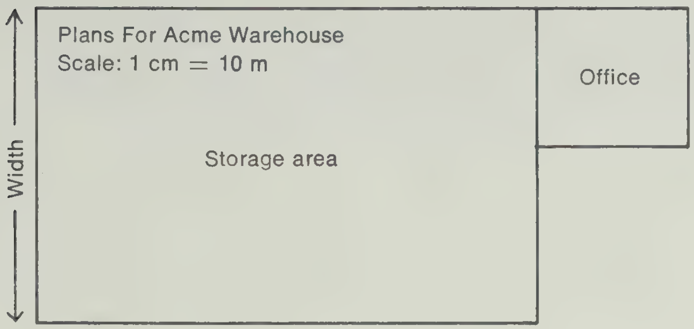
1. If you know the scale of a drawing, you can determine the size of the object drawn.
2. The actual size of an object is equal to the measurement on the drawing multiplied by the scale used.
3. Actual distances can be found from a map by using the scale in the same way.

Answers to Checkup 5-1
1. 4 metres
2. 3.5 metres

If you missed either of these questions, do this excursion before returning to Chapter 5.

If you know the scale used in a drawing, you can determine the actual size of the object drawn. Look at Figure 1. It is a simple plan for a new building.

Figure 1



☐ **1.** What scale did the architect use?

☐ **2.** How many centimetres wide is the storage area as shown in the drawing?

☐ **3.** When the warehouse is actually built, how wide will the storage area be?

Your answer to question 2 should be 4 cm. The answer to 3 should be 40 m. (This results from multiplying 4×10. Remember that 1 cm on the drawing represents 10 m in the finished building.)

☐ **4.** Use the information in Figure 2 to answer these questions:

Figure 2

Answers given are in round numbers. If you are consulted about any missed parts to the question, you will have to use your judgment concerning further action. It may only require a moment of time to straighten out the difficulty, or it may indicate that the student should repeat the excursion. You might even want to devise another simple exercise on scale drawings for additional practice.

What is the actual distance
A. from Boston to Chicago?
B. from Chicago to San Francisco?
C. from Chicago to New Orleans?

If your answers to question 4 were A. 1344 km, B. 2880 km, and C. 1344 km, you are ready to continue with Chapter 5. If you missed any of the parts to question 4, consult with your teacher before going ahead.

Excursion 5-3
Practice in Using Scale Drawings

EQUIPMENT LIST

Metric ruler

PURPOSE

To give additional practice in measuring on a scale drawing and using the measurements to find actual distances.

MAJOR POINT

Actual distances can be found by multiplying the distances measured on a drawing by the scale of the drawing.

This is a remedial excursion that is designed to help those who are having difficulty finding the required distances at the end of Chapter 5.

How can you find the distances from Earth to the sun and Venus to the sun by using a scale drawing? The sketch in Figure 1 is a scale drawing. Measure the distances shown on the drawing: VS, ES, and EV. Try it.

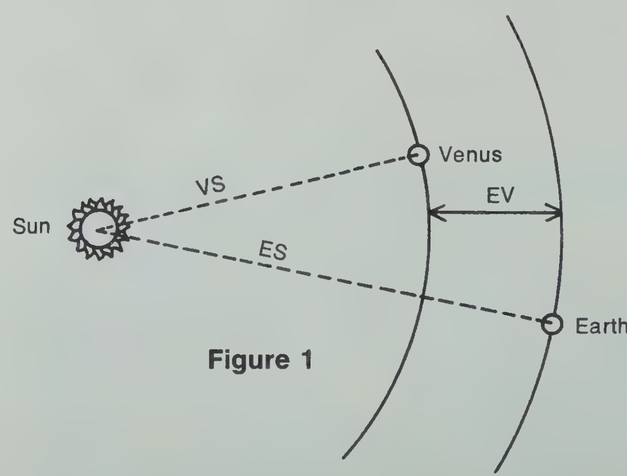


Figure 1

Compare your results with the figures in Table 1. Remeasure any distances that do not agree with the numbers in the table.

	Scale drawing (mm)	Actual distance (km)
Venus to Sun **(VS)**	43	?
Earth to Sun **(ES)**	60	?
Earth to Venus **(EV)**	17	42 000 000

Table 1

☐ **1.** From Table 1 you see that 17 mm on the drawing represent 42 000 000 actual km. How many actual km would be represented by 1 mm? Of course, $\frac{1}{17}$ as many km, or 1 mm on the drawing, represents $\frac{1}{17} \times 42\,000\,000$ actual km = how many km?

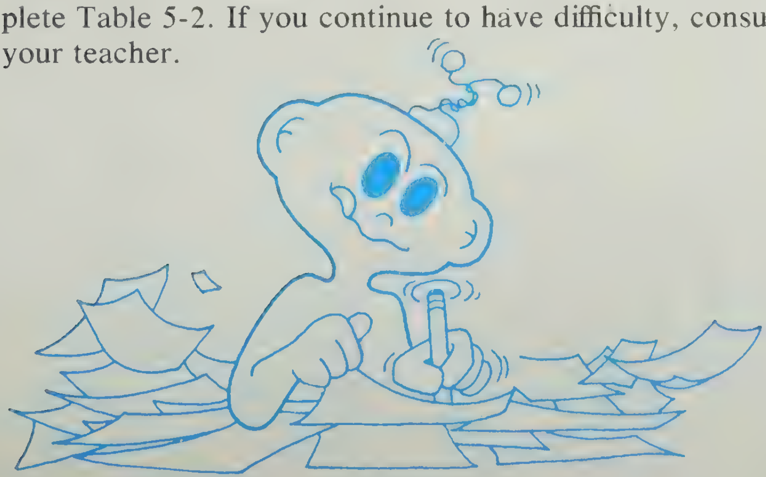
☐ **2.** How many actual km would represented by 2 mm on the drawing?

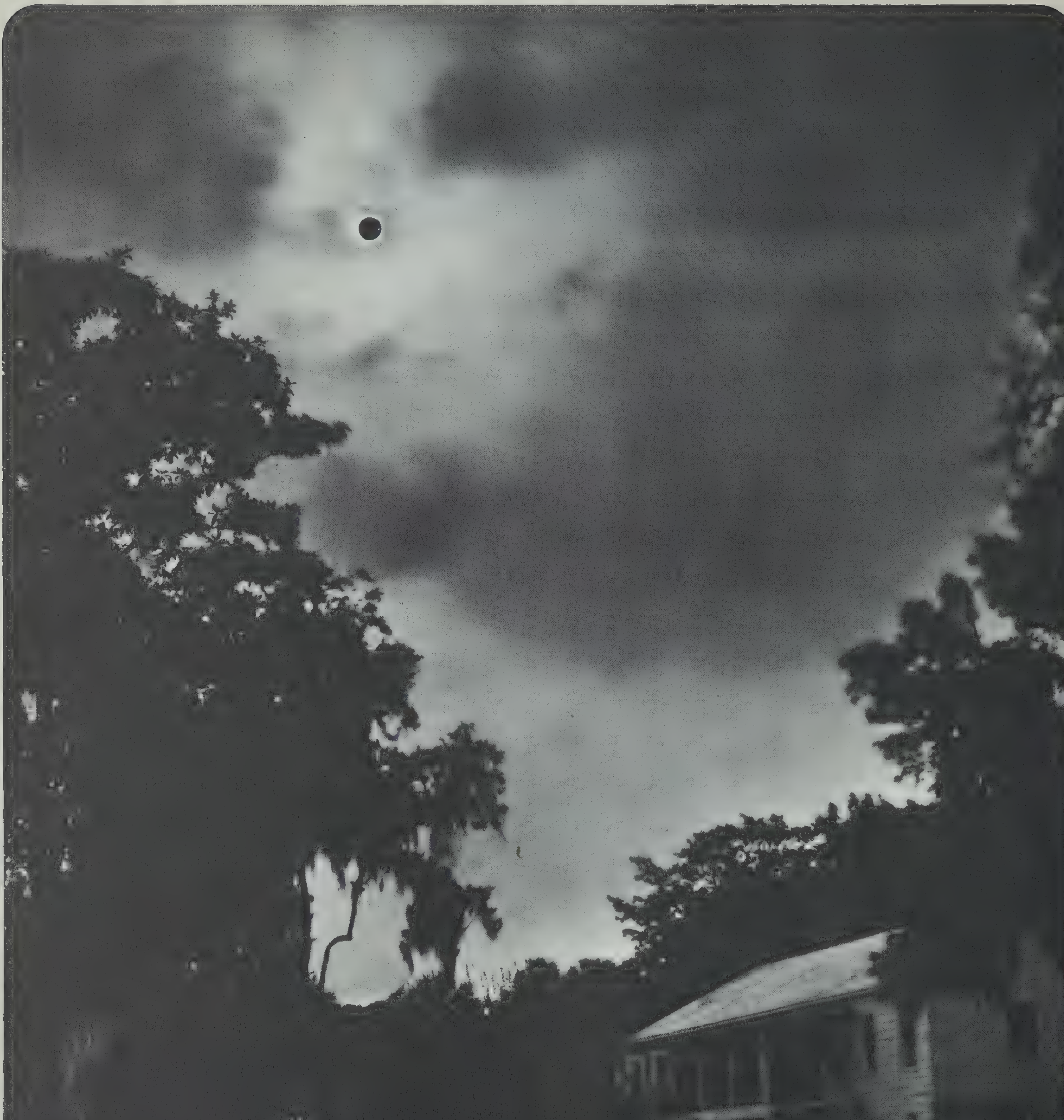
☐ **3.** Now figure out the Venus–sun distance for Table 1. How many actual km are represented by 43 mm? Forty three mm in the drawing represent $\frac{43}{17} \times 42\,000\,000$ actual km = how many km?

☐ **4.** Using the same method, you can find the Earth–sun distance. The Earth–sun distance on your drawing is 60 mm. How many actual km are represented by 60 mm?

You should have gotten about 106 000 000 actual km as an answer for question 3. About 148 000 000 actual km should be your answer for 4. Record these results in Table 1 in your Record Book. Now return to Chapter 5 and complete Table 5-2. If you continue to have difficulty, consult your teacher.

If the student is still having difficulty at this point, and consults you, it may help to break the "system" into its components to try to locate the trouble. The system of getting actual distances from a scale drawing involves two subsystems:
1. Making the measurement.
2. Converting the measurement to distance.
Under "making the measurement" could be the components of (a) using the proper scale (if there is more than one) on the ruler, (b) placing the ruler on the proper line, (c) having the zero of the ruler on one end of the line, (d) reading the ruler correctly.
Under "converting the measurement to actual distance" could be the components of (a) using the proper mathematical operation (multiplication), (b) multiplying correctly, and (c) copying the result correctly.





How Big Is the Sun?

Excursion 6-1 is keyed to this chapter.

6

CHAPTER EMPHASIS

The size of a distant object may be measured by projecting its image on a screen and using a simple mathematical relationship.

FILMSTRIP KEY

Measuring The Sun's Size

EQUIPMENT LIST

Per student-team

1 cardboard sighting scope, with frosted grid
1 150-watt bulb and socket
1 metrestick
Tape

MAJOR POINTS

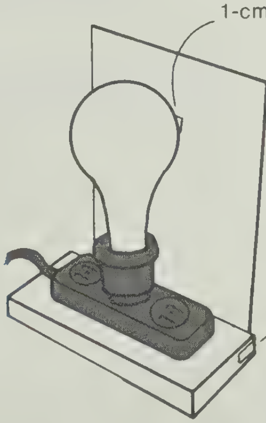
1. An image of a bright object can be projected through a pinhole onto a screen.
2. There is a mathematical relationship between size of object, size of image, distance from pinhole to object, and distance from pinhole to image.
3. This relationship can be used to find the diameter of the sun, when the distance to the sun is known.
4. The sun is a huge body more than 100 times the diameter of the earth.
5. It is possible to measure objects at great distances.

In this chapter another measurement of the sun is made. This time you will try to find out how far it is across the sun. Obviously, measuring the distance across an object that is 149 million km away is a bit complicated.

But with a little thought, the job can be done fairly easily. To make your measurements, you and a partner will need these materials:

1 cardboard sighting scope, with frosted grid
1 light-intensity board
1 150-watt bulb and socket
1 metrestick
Tape

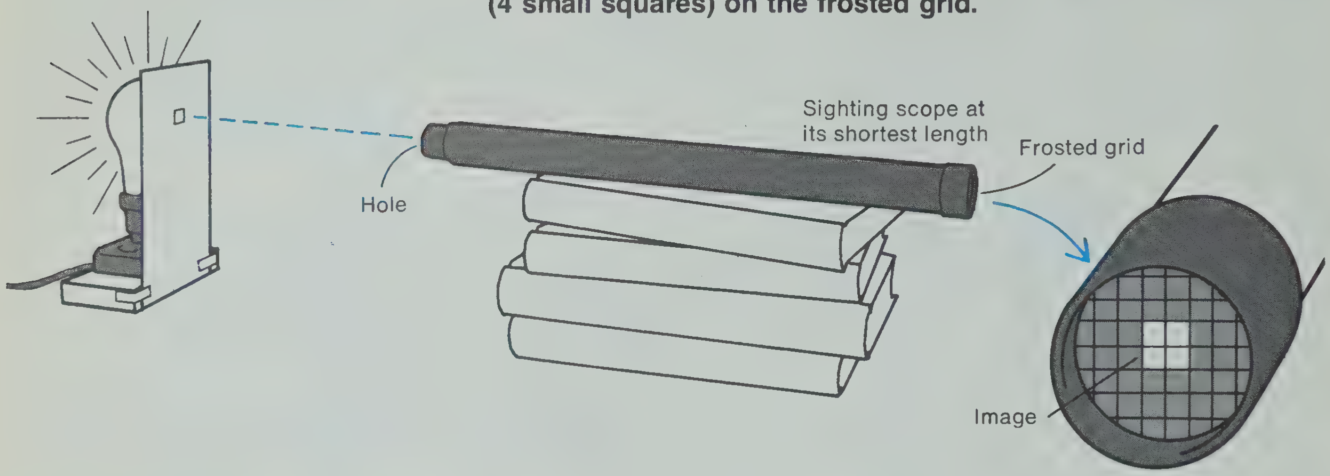
See instructions in the Teacher's Front Matter for making the cardboard sighting scope. Be sure that the 1-cm hole in the light-intensity board is square and lines up with the brightest part of the bulb when mounted.



ACTIVITY 6-1. Tape the light intensity board in front of the light bulb as shown. Be sure the brightest part of the bulb is lined up with the square hole.

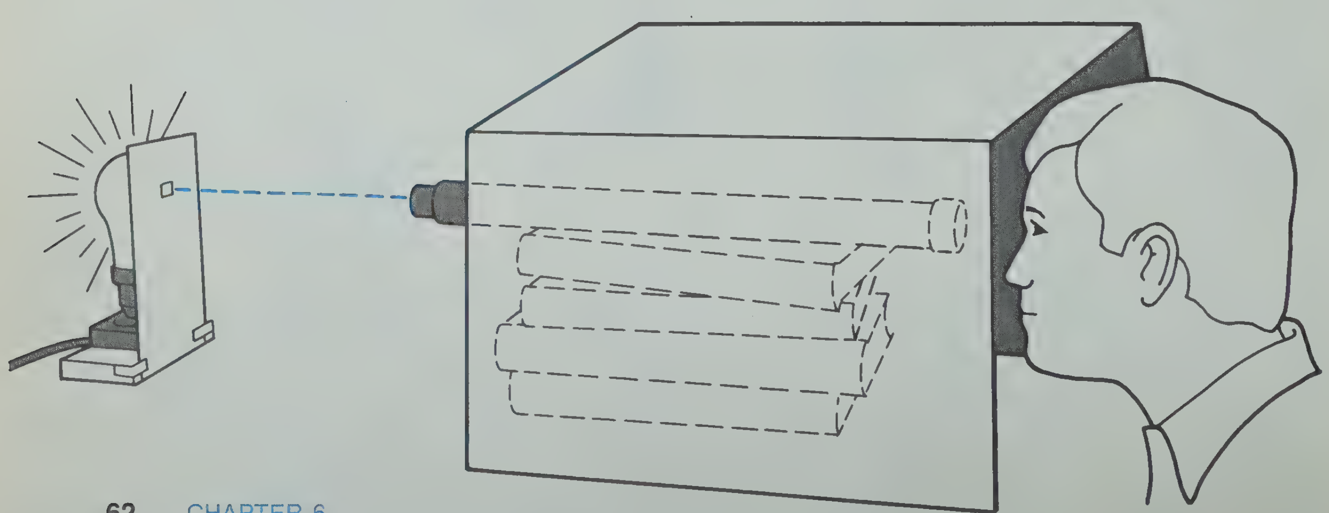
For what follows, you will need a level space behind the bulb of up to 1 metre and about 1 metre in front of the bulb. This space is needed so either the bulb or sighting scope can be removed.

ACTIVITY 6-2. Support the sighting scope on books so that it is level. The tube should point straight at the square hole. The end with the pinhole should be pointed toward the light. Have the tube at its shortest length (small tube pushed in all the way). Gradually move the light bulb and cardboard away from the tube until an image of the square hole just fills 1 cm^2 (4 small squares) on the frosted grid.



As the light source is moved away from the pinhole, the image will be much dimmer. It will be even more important to have the screen protected from extraneous light.

ACTIVITY 6-3. To see the square image on the frosted grid, you must look straight into the screen. It helps if the screen is in a darker part of the room. You may want to use large cardboard cartons as light shields around the ends of the telescoping tubes. When you see the image, you can measure distances needed to answer the questions that follow.



☐ **6-1.** What is the distance (in cm) from the pinhole to the square hole in the light-intensity board?

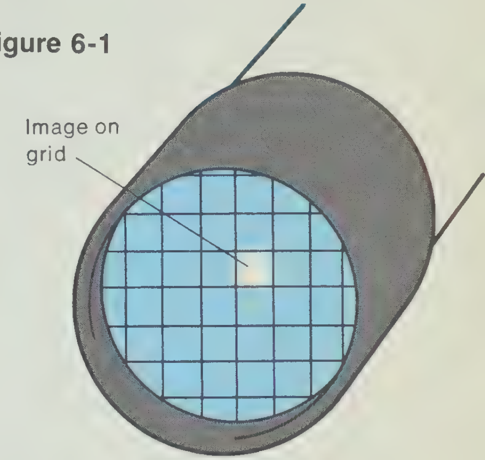
☐ **6-2.** What is the distance (in cm) from the pinhole to the grid (the length of the cardboard tube)?

With the telescoping tube at its shortest length, the distances for questions 6-1 and 6-2 should both be about 42 cm.

Hopefully you've made careful measurements. You've found the distance from the pinhole to the grid. The distance from the pinhole to the square hole in the card should be about the same distance. The square hole is the light source.

Now move the light-intensity board away from the pinhole. Move it until only one square on the grid is filled with the image. See Figure 6-1.

Figure 6-1



☐ **6-3.** Now what is the distance (in cm) from the pinhole to the square hole in the light-intensity board?

The new distance you just measured should be about twice the distance from the pinhole to the grid.

☐ **6-4.** How many times bigger is the distance across the square hole in the cardboard (1 cm) than the distance across the image (0.5 cm)?

Perhaps you are beginning to see some relationships here. The distance from the pinhole to the screen and the size of the image are related. You can use this relationship to measure the size of a bright object such as the 150-watt bulb. Let's see how this can be done.

Here's the relationship you need.

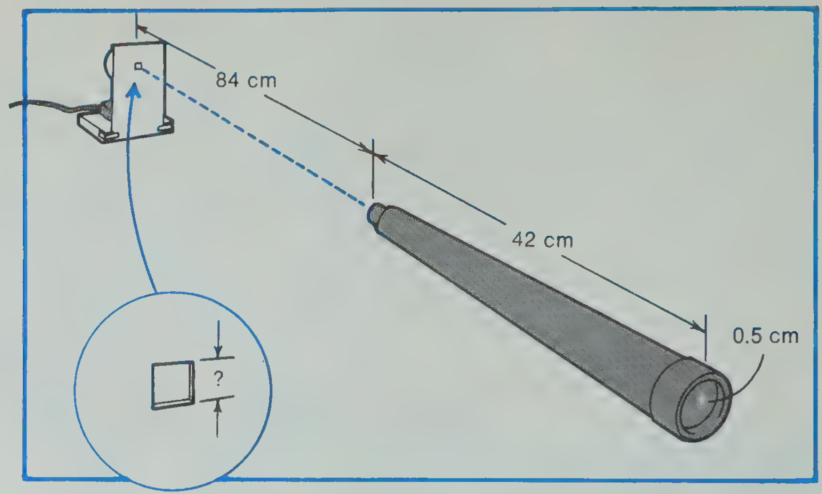
You may recognize this mathematical relationship as the modified lens formula: $\frac{Ho}{Hi} = \frac{Do}{Di}$, where Ho = size of object, Hi = size of image, Do = distance from pinhole to object, and Di = distance from pinhole to image.

$$\text{Distance across the object (the square hole in the intensity board)} = \frac{\text{Distance from the object to the pinhole}}{\text{Distance from the pinhole to the grid}} \times \text{Distance across the image on the grid}$$

Here's an example of how the relationship can be used.

The distance from the pinhole to the square hole in the cardboard is 84 cm. The distance from the pinhole to the grid (the length of the tube) is about 42 cm. The width of the image on the grid is 0.5 cm. All of this is shown in Figure 6-2.

Figure 6-2

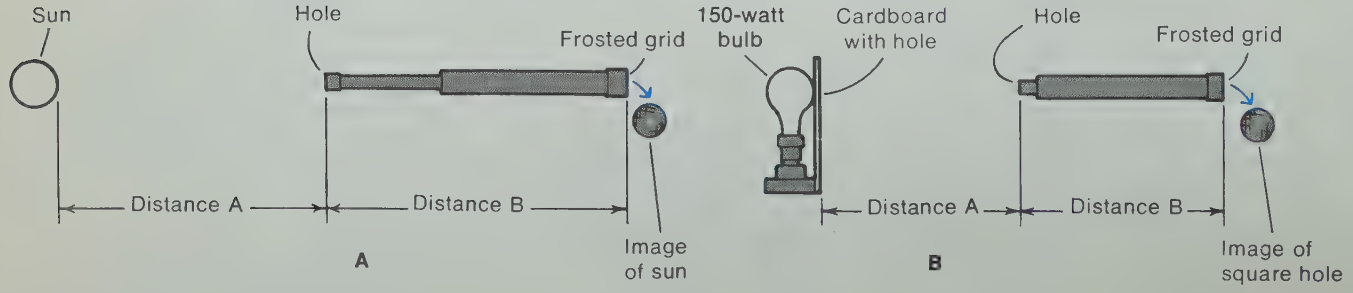


$$\text{Distance across the square hole} = \frac{84\text{ cm}}{42\text{ cm}} \times \text{distance across the image}$$
$$= \frac{84\text{ cm}}{42\text{ cm}} \times 0.5\text{ cm}$$
$$= 2 \times 0.5\text{ cm}$$
$$= 1\text{ cm}$$

Now check to be sure that your answers to questions 6-1, 6-2, 6-3, and 6-4, fit the relationship. For example, in order for your answers to 6-1 and 6-2 to fit, they must be equal. This is because the object and image width are the same size at that setting.

Part A in Figure 6-3 shows how you can calculate the distance across the sun. You can do it the same way that you just calculated the distance across the hole in the light-intensity board (Part B of Figure 6-3). All you need do is set up the sighting scope so that the pinhole faces the sun. When the scope is lined up, the sun's image will fall on the screen.

Figure 6-3



Safety Note *Remember, you should never look directly at the sun. Do not look through the sighting tube at the sun.*

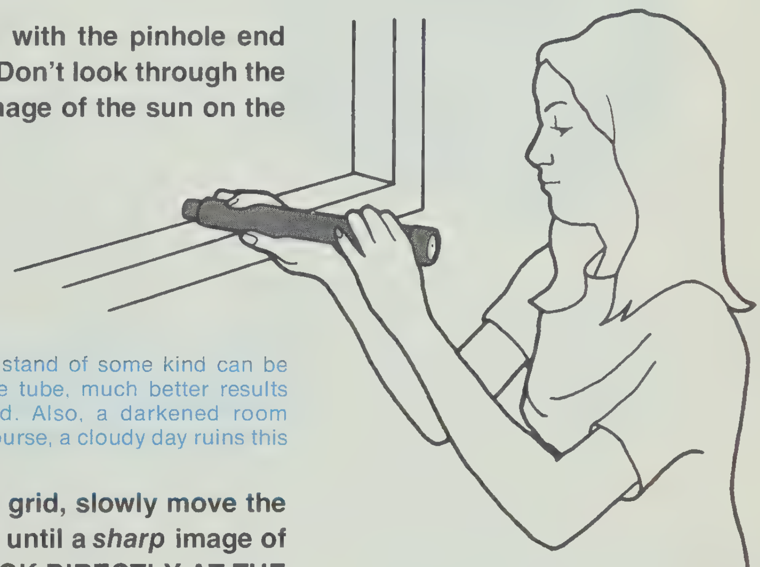
Even though there is a safety note for the students, it might be wise to remind them that, although they looked directly into the screen when getting the square image with the light bulb, they should not use the same technique with the sun. However, the sun's image is so much brighter that it can easily be seen without looking directly.

Once you have an image of the sun on the grid, you can get everything needed to calculate the distance across the sun. You've already calculated the distance from the sun to the pinhole—149 million km. This is the distance of the sun from Earth. Thus:

$$\text{Distance across the sun} = \frac{149\ 000\ 000\ \text{km}}{\text{Distance from pinhole to grid}} \times \text{Distance across the image}$$

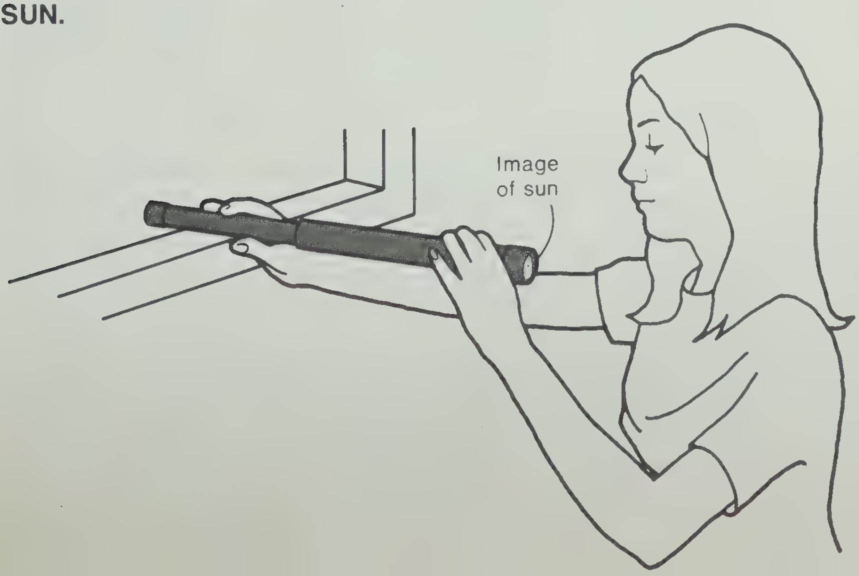
Now you need to measure the width of the image on the screen.

ACTIVITY 6-4. Try to line up the tube with the pinhole end pointing directly at the sun as shown. Don't look through the tube. Sight down it until you get an image of the sun on the grid.



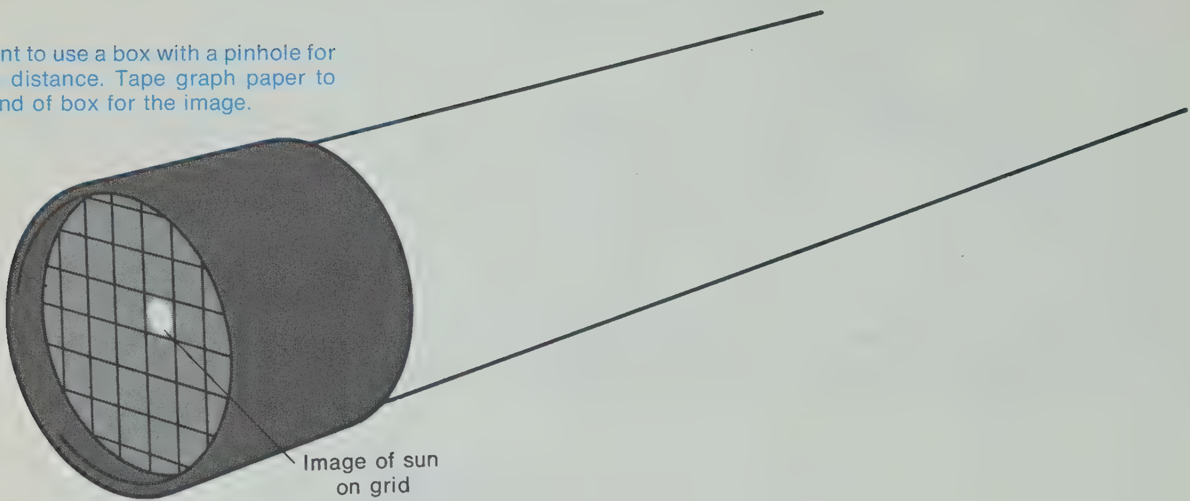
If an adjustable stand of some kind can be used to hold the tube, much better results can be achieved. Also, a darkened room helps a lot. Of course, a cloudy day ruins this activity.

ACTIVITY 6-5. Once sunlight is on the grid, slowly move the two sections of the tube apart. Do this until a *sharp* image of the sun forms on the grid. DO NOT LOOK DIRECTLY AT THE SUN.



ACTIVITY 6-6. Continue to adjust the length of the tube. The image of the sun should just fit inside one of the 0.5-cm squares. It should just touch the four sides of the square. Measure the distance from the grid to the pinhole (the total length of the tube).

You may want to use a box with a pinhole for establishing distance. Tape graph paper to the inside end of box for the image.



If the student has made careful measurements, the distance from the pinhole to the screen should be about 54 cm (question 6-5). Anywhere in the 52–58 cm range should be considered adequate. The image of the sun, though distinct, is fuzzy enough on the screen to make it difficult to exactly fit it into one square. Using 54 cm, the distance across the sun (question 6-6) becomes 1 380 000 km. The diameter generally used in astronomy is 1 390 000 km. An answer anywhere between 1 340 000 km and 1 440 000 km should be acceptable.

GET IT READY NOW FOR CHAPTER 7

Small pieces of cardboard and string will have to be supplied locally. Students will also need a sheet of white paper.

Excursion 6-1, "Moon Gazing," is a fun exercise in which the student constructs a simple telescope not too unlike the one made by Galileo.

EXCURSION

☐ **6-5.** What is the distance in cm from the pinhole to the grid?

Now you have all the data you need to calculate the distance across the sun by using the relationship.

$$\text{Distance across the sun} = \frac{149\ 000\ 000\ \text{km}}{\text{Distance from pinhole to grid in cm}} \times 0.5\ \text{cm}$$

☐ **6-6.** What is the distance across the sun in km? (If you make the calculation shown above, your answer will automatically come out in km because the centimetres cancel out.)

You may have been surprised to learn how large the sun really is. Its diameter is far greater than the diameter of the moon's orbit around the earth. You should also realize that with careful thinking and a few measurements and calculations, astronomers can provide answers that at first seem impossible to get.

If you would like to make your own telescope and get a good look at the moon, do **Excursion 6-1,** "Moon Gazing."

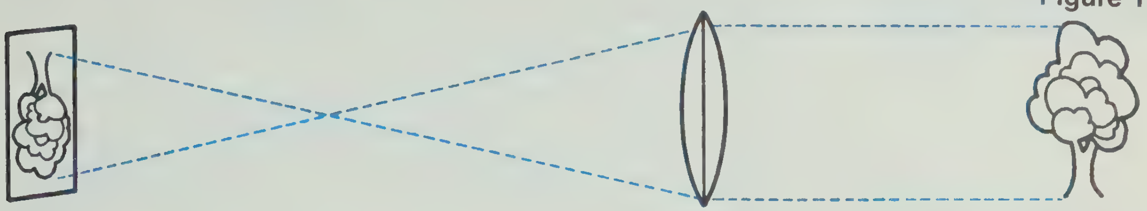
Before going on, do Self-Evaluation 6 in your Record Book.

A Dutch eyeglass maker, Hans Lippershey, discovered the principle of the telescope. He found that an eyeglass lens can focus light coming from a distant object. As light passes through the lens, the light rays are brought closer together. They eventually cross and can form an image on a flat surface. The crossing of the light rays produces an upside-down image of the object. Figure 1 illustrates this.

Excursion 6-1
Moon Gazing

This is a general-interest and extension excursion.

Figure 1

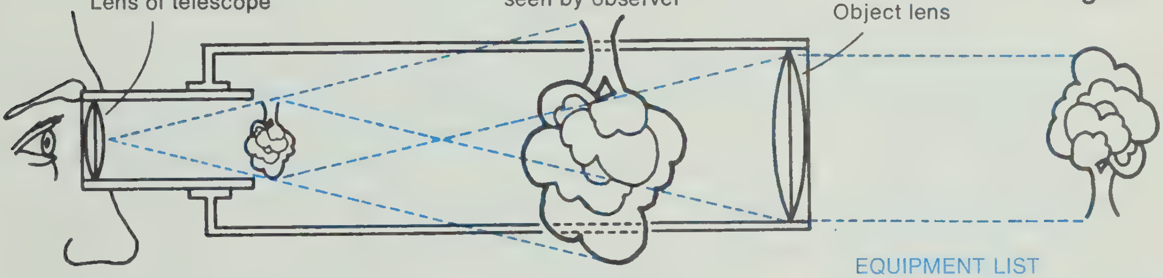


Lippershey found that such a lens could be placed in one end of a cylinder. A smaller lens, placed at the other end, could be used to magnify the image. See Figure 2.

PURPOSE

To construct a simple astronomical telescope and study the principles of its operation.

Figure 2



Lippershey probably didn't think of using his telescope to look at the stars or moon. But others who heard of the new device did. Soon instruments were being made just for that purpose. The scientist Galileo made his own telescope and used it for sky gazing. Perhaps you've heard of him. He's the same fellow who tested the idea that objects with different masses fall at the same rate.

People who use telescopes don't just want to see distant objects. They want to see as much detail as possible. To understand how this is achieved, you need to know a bit more about the lenses in the telescope.

The distance from the object lens to its focus is called the *focal length of the object lens*. Likewise, the distance from the eyepiece lens to its focus is the *focal length of the eyepiece*.

EQUIPMENT LIST

1 sighting scope
1 object lens, 34 mm in diameter
1 eyepiece lens, 25 mm in diameter
1 piece white cardboard, 15 cm square
1 metrestick
Masking tape
1 sliding lens holder
1 150-watt bulb and socket

MAJOR POINTS

1. A lens can focus light rays from an object to form an inverted image.
2. A lens can be used to magnify an image.
3. The distance from the lens to its focus is called the focal length of the lens.
4. The power of a telescope is equal to the focal length of the object lens divided by the focal length of the eyepiece.
5. An astronomical telescope forms an inverted image.

6. The diameter of the object lens is a measure of the light-gathering ability of the lens.

The study of lenses and their uses in telescopes can be a complete subject in itself, and is far beyond the capabilities of the student at this point. For your information, the type of telescope discussed in this excursion is called a refractor, because it focuses light by refraction, or bending. The largest refracting telescope of this kind is the 40-inch instrument at Yerkes Observatory. This is about thirty times the diameter of the 34-mm lens used here. The light-gathering ability is proportional to the square of the diameter, so the Yerkes instrument collects 30 squared, or 900, times as much light. Instruments larger than this have been found to be impractical because of the tendency of the huge lens to sag, distorting the image. Thus, all the larger telescopes today are reflectors, which form an image by the reflection of light. The mirror can be adequately supported from the rear, so there is little distortion. The largest of these in use at present is the 200-inch Hale reflector, which gathers over 22,000 times as much light as your little lens. With this amount of light to work with, eyepieces can be used that give tremendous magnifications.

The power or magnification of a telescope is calculated by using the following equation.

$$\text{Power} = \frac{\text{Focal length of object lens}}{\text{Focal length of eyepiece}}$$

☐ **1.** Suppose a telescope has an object lens with 30-cm focal length and an eyepiece lens with 5-cm focal length. What is the power of the telescope?

The greater the focal length of the object lens as compared with the focal length of the eyepiece, the greater the magnification. However, when you magnify size, you also magnify the effect of motion. So the greater power the telescope has, the steadier it must be held. Even the slightest motion may make the image seem to float. It appears to bob up and down and sideways like a cork on a windswept pond. You've probably noticed this effect with binoculars.

☐ **2.** Why are giant telescopes at observatories placed on massive concrete foundations?

Perhaps you'd like to construct an instrument similar to the one Galileo made, and use it as he did. You can observe the surface of the moon, its craters, flat plains (called seas), and mountains. If so, you will need the following equipment:

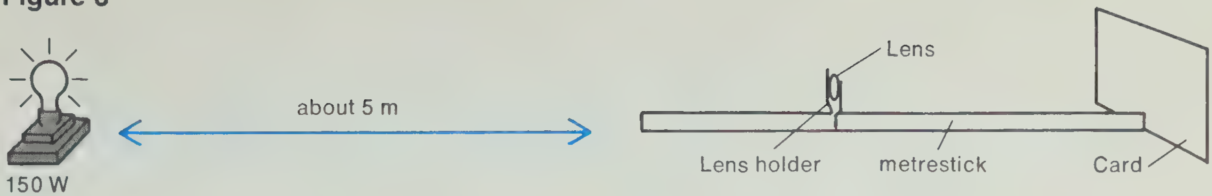
1 object lens, 34 mm in diameter
1 eyepiece lens, 25 mm in diameter
Sighting scope
1 cardboard, 15 cm square, with white surface
Metrestick
Masking tape
Lens holder
1 150-watt bulb and socket
Tissue

To know the power your telescope has, you need to find the focal lengths of the two lens. Be careful in handling them. Do not drop them, as they break easily.

You'll need a place to set up as shown in Figure 3.

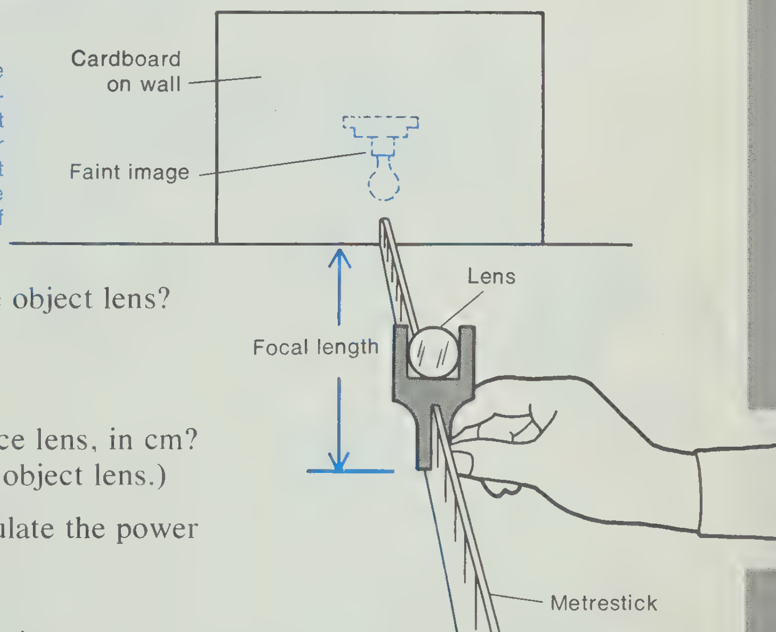
You will be trying to focus the light from the bulb through the lens onto the card. To start, go to the darkest part of the room and prop the cardboard flat against the wall.

Figure 3



ACTIVITY 1. Put the object lens (the larger lens) in the lens holder. Mount it on the metrestick in front of the cardboard. Move the lens toward or away from the cardboard until a clear image of the light bulb appears on the cardboard. The distance from the lens to the cardboard will then be the focal length of the lens. Use the metrestick to measure this distance.

The lenses supplied are supposed to have focal lengths of 45.3 cm and 4 cm respectively (questions 3 and 4). This means that the power in question 5 will be a little over 11. You may want to check the lenses that are supplied. However, Activity 5 will give you an approximate measure of the sum of the focal lengths.



☐ **3.** What is the focal length, in cm, of the object lens?

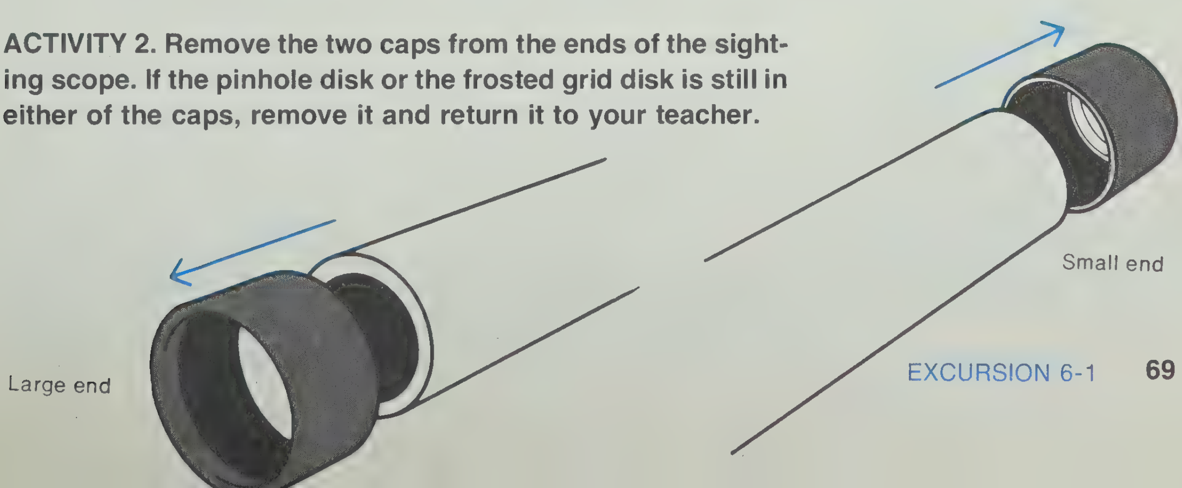
Repeat Activity 1 with the eyepiece lens.

☐ **4.** What is the focal length of the eyepiece lens, in cm? (It should be much shorter than that of the object lens.)

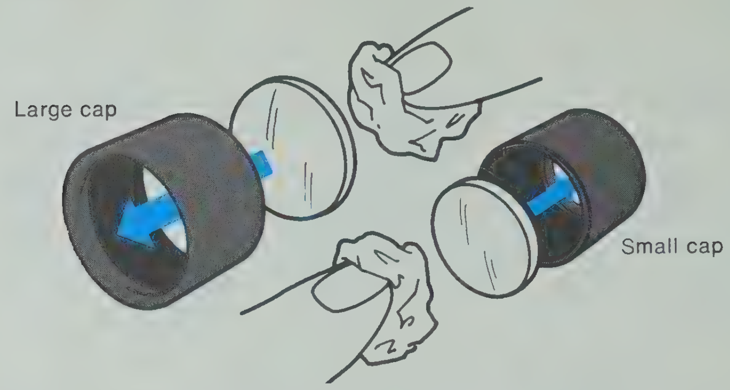
☐ **5.** Using the equation given earlier, calculate the power of your telescope.

Now continue with the telescope construction.

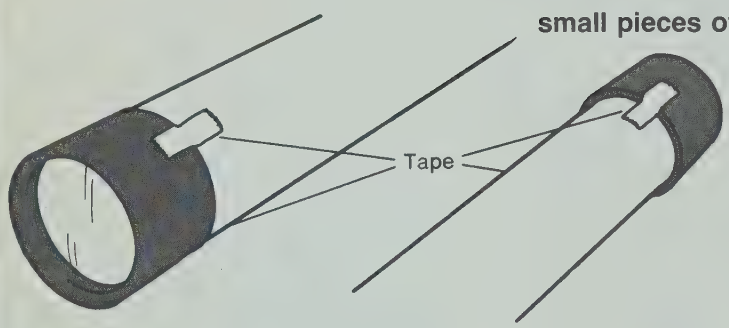
ACTIVITY 2. Remove the two caps from the ends of the sighting scope. If the pinhole disk or the frosted grid disk is still in either of the caps, remove it and return it to your teacher.



ACTIVITY 3. Use tissue to clean the lenses. Then with tissue between your finger and the lens, slide the larger lens into the large cap and the smaller lens into the small cap. The tissue will help keep fingerprints off the lens.



ACTIVITY 4. Replace the caps on the tubes. Secure them with small pieces of tape.



An 11-power telescope is comparable to the ones Galileo constructed. At a magnification of 11 diameters, tiny motions are magnified the same amount. The scope must be steadied in order to see anything clearly.

Take your telescope to the window. Rest it on the ledge or against the window and point it toward a distant object. DO NOT LOOK AT THE SUN. Hold the eyepiece close to your eye. Slide the outer tube out or in until you can see a sharp image of the object.

Safety Note *Remember, do not look at the sun.*

☐ **6.** Describe anything different about the image that you observe. (Different means from what you would see with the naked eye.)

Besides magnifying, your telescope did something else that was unusual. You should have described it above. This is common with astronomical telescopes. However, it is not bothersome to astronomers.

6. The image is inverted (upside-down). This trait is not bothersome to astronomers (question 7) because it makes little difference to them whether a celestial object is viewed inverted or erect. In addition, most modern astronomy is done photographically, because long exposures can give much greater sensitivity. Thus, the picture need only be turned to give an erect image.

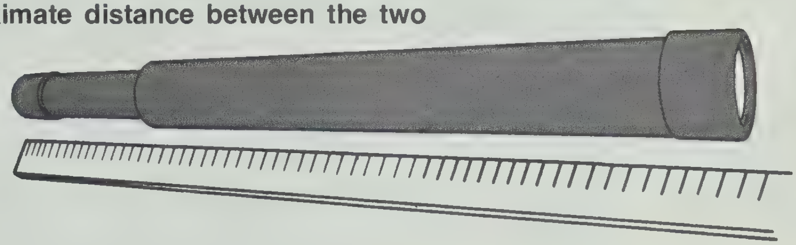
In terrestrial telescopes (and opera glasses, etc.) it is bothersome to see things inverted, so another lens is usually inserted between the object lens and the eyepiece so that the object may be viewed erect.

☐ **7.** Why would what you observed not be bothersome to astronomers?

There is a length where your telescope will give maximum magnification. That's when the distance between the object and eyepiece lenses is about equal to the sum of their focal lengths.

☐ **8.** How far apart should the lenses be in your telescope to give it the maximum magnification? (See your answers to questions 3 and 4.)

ACTIVITY 5. Sight a far object to adjust your telescope for maximum magnification. Then measure along the outside of the case to get the approximate distance between the two lenses.



You may notice differences between what you measured in Activity 5 and what you predicted in question 8. This is usually due to individual eye differences (assuming you answered question 8 correctly).

Suppose you bought a telescope, field glasses, or binoculars. You might see two numbers listed in the descriptive literature. You might, for example, see "8 × 30" (read "eight by thirty"). The first number is the power—in this case, a magnification of 8 times. The second number gives the diameter of the object lens in millimetres—in this case 30 mm. The latter figure is important. It tells you the light-gathering ability of the instrument. The higher this number is, the more light it allows to enter the instrument. Instruments with greater light-gathering ability work better at night.

☐ **9.** Give the descriptive numbers for the power and light-gathering ability of your telescope.

Ask your teacher if you may use your telescope at night to observe the moon. You should be able to identify some of the moon's features.

9. At face value, the descriptive numbers would be 11.3 × 34. Actually, the power would probably be given to the nearest whole number—11. Examination of the telescope shows that, although the lens is 34 mm in diameter, the inside diameter of the larger tube limits the effective size of the lens to 25 mm. Thus, the numbers could better be stated as 11 × 25. But even with only 25 mm usable, the little telescope has remarkable light-gathering ability. It has a diameter about 5 times as great as the pupil of an eye, so it would gather 25 times as much light.

You will have to be the judge on the use of the instrument outside of school. Actually, it can be a stimulating experience for the student. With a similar instrument, Galileo mapped the surface of the moon, described the appearance of mountains on the terminator, discovered 4 moons of Jupiter, and observed the phases of Venus.

The Fiery Chariot

7

EQUIPMENT LIST

Per student-team

1 drawing compass
1 metric ruler
1 lead sinker
1 50-cm piece of string
1 protractor
1 sheet of white paper
Masking tape
Cardboard
Scissors
Clay
1 map pin
1 straight pin

CHAPTER EMPHASIS

The relative motion between the sun and an observer is examined, and the effects of this motion are studied.

Excursions 7-1 and 7-2 are keyed to the chapter, and Resource 9 is rekeyed.

FILMSTRIP KEY
(Enrichment)

Ptolemy, Copernicus, and Galileo

MAJOR POINTS

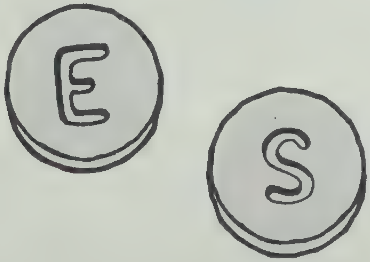
1. From observations of the apparent motion of the sun, it is impossible to tell whether the sun is moving and the earth is stationary or the earth is rotating and the sun is standing still.
2. The apparent motion of the sun is through 360° every 24 hours, or 15° per hour.
3. The time zones in use are based on this apparent motion of 15 degrees per hour.
4. The apparent path of the sun across the sky changes from day to day.
5. The apparent speed of the sun can be measured by the motion of the shadow that it casts.
6. The apparent speed of the sun is a very large number of kilometres per hour.
7. Because of this extremely high speed, the model that the sun moves around the earth each day is unlikely.

One of the myths told in ancient times described the sun as a flaming ball carried across the sky in a chariot drawn by four horses. Since you formed an image of the sun on a screen in Chapter 6, you know that part of the myth is in fact true. The sun is a flaming ball.

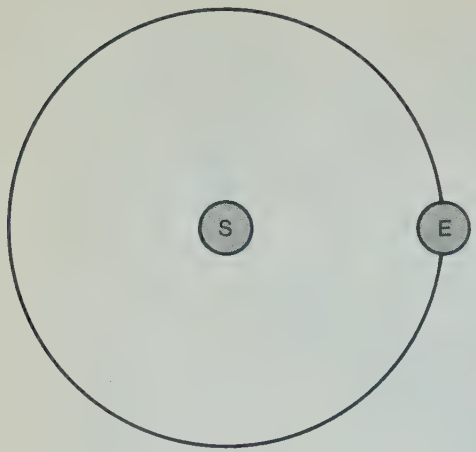
But does the sun move across the sky? To you, the answer is probably a solid No. You know that the earth's turning is what makes the sun appear to move. Proving this is not easy. To someone on the earth, the sun moving around an unmoving earth appears the same as a still sun with the earth turning. A simple model can show you why.

Use the following materials:

1 printed circle (7.45 cm radius) from your Record Book
Small ball of clay
1 map pin
2 straight pins

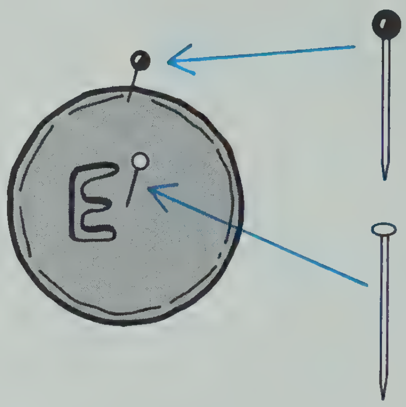


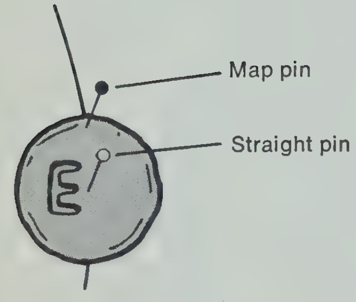
ACTIVITY 7-1. Divide the clay into two pieces and make small pancakes about the size of those shown. With your pencil tip, scratch a letter in each as shown. The "S" clay disk will represent the sun. The "E" clay disk will represent the earth.



ACTIVITY 7-2. Place the sun in the center of the printed circle in your Record Book. The circle is 7.45 cm in radius or 14.9 cm in diameter. Then place the earth on the circle as shown.

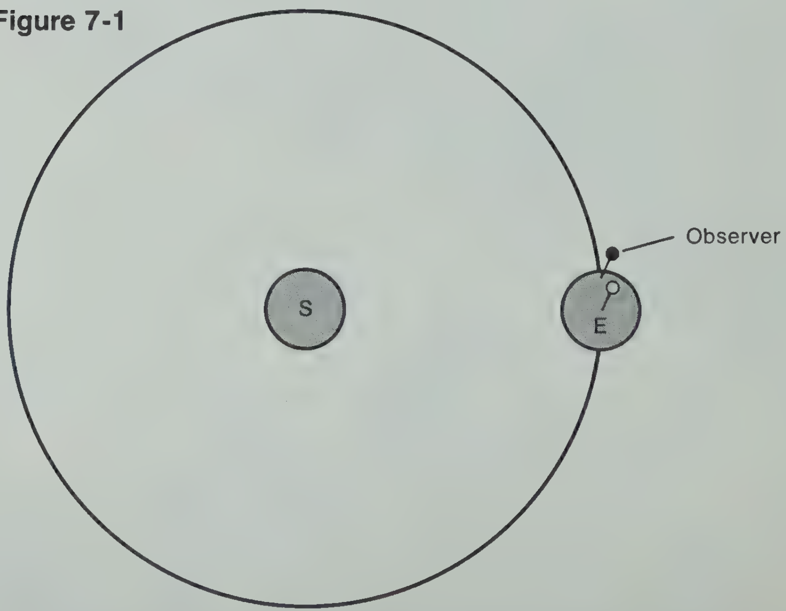
ACTIVITY 7-3. Place a straight pin into the center of the earth disk. Then put the map pin into the edge of the disk as shown.





The straight pin represents the north pole. The map pin represents an observer on the equator.

Figure 7-1



7-1. The sun would appear to be on the horizon (actually, on the eastern horizon).

☐ **7-1.** Suppose you were the observer standing on the earth in Figure 7-1. Would the sun appear to be overhead, or on the horizon?

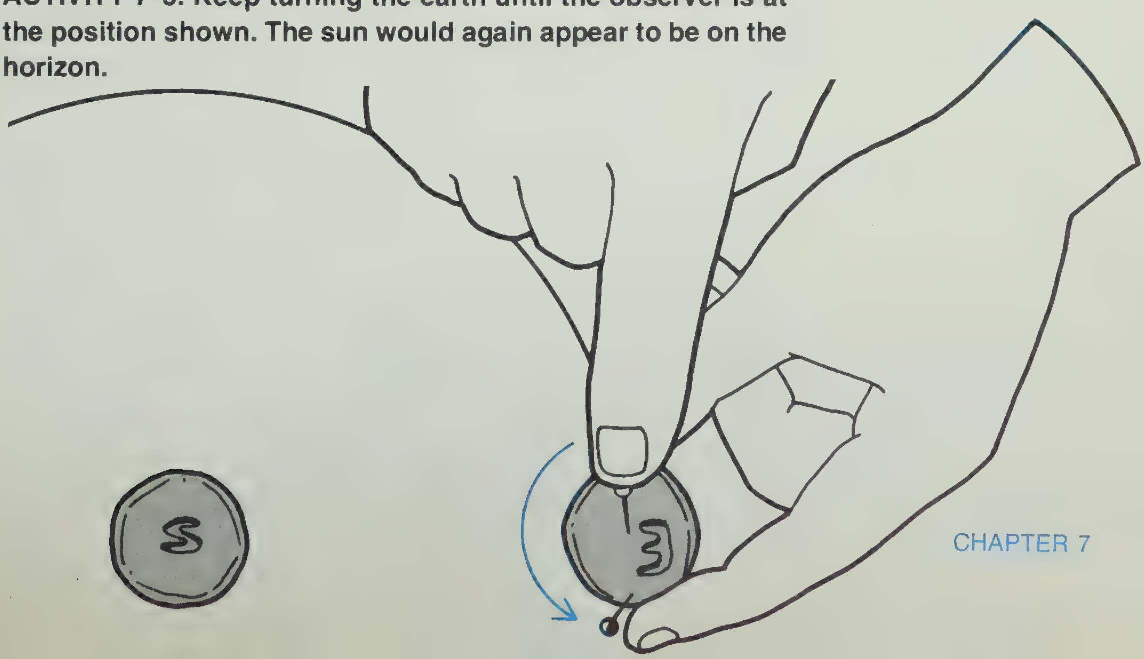
ACTIVITY 7-4. Push the straight pin through the disk. Then turn the earth around the straight pin until the observer is in the position shown.

☐ **7-2.** In Activity 7-4, would the sun appear to be overhead to the observer?

☐ **7-3** How many degrees did you have to turn the earth to get the sun overhead? (Hint: If you have trouble with this question, see **Resource 9,** "Measuring Angles.")

RESOURCE

ACTIVITY 7-5. Keep turning the earth until the observer is at the position shown. The sun would again appear to be on the horizon.

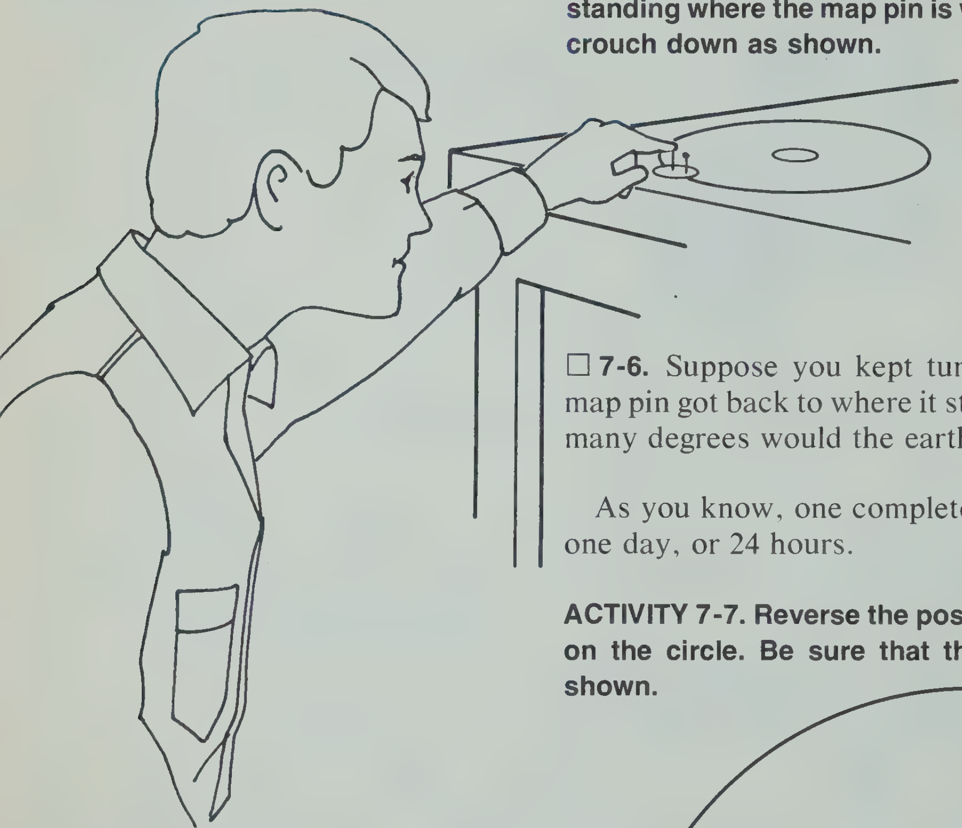


☐ **7-4.** How many degrees have you turned the earth from where it started (in Figure 7-1)?

☐ **7-5.** To the observer represented by the map pin, would the sun seem to have traveled across the sky from one horizon to the other?

7-6. 360°. It is important that the student sees the connection between the degrees (360) and the hours (24).

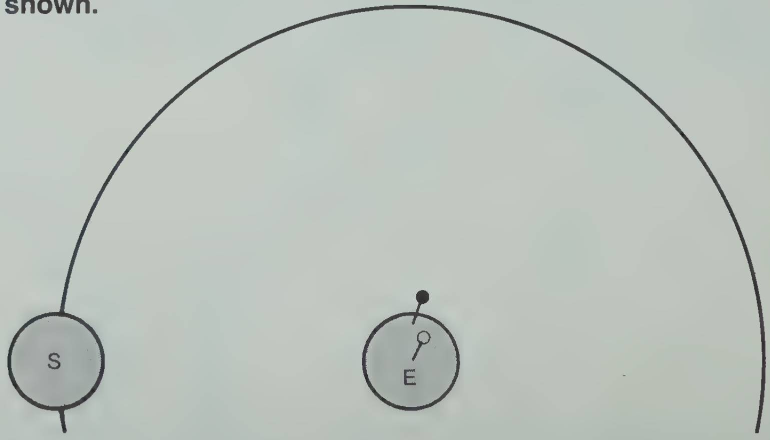
ACTIVITY 7-6. Check your answer to question 7-5 by repeating Activities 7-4 and 7-5. Try to visualize what a person standing where the map pin is would be seeing. It may help to crouch down as shown.



☐ **7-6.** Suppose you kept turning the earth disk until the map pin got back to where it started. Through a total of how many degrees would the earth disk have turned?

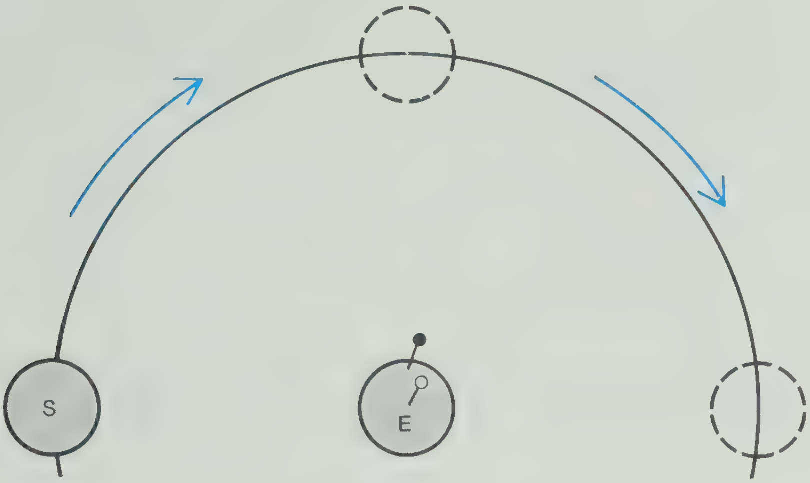
As you know, one complete turn of the earth represents one day, or 24 hours.

ACTIVITY 7-7. Reverse the positions of the earth and the sun on the circle. Be sure that the observer faces upward as shown.



☐ **7-7.** With the earth and the sun in the position shown in Activity 7-7, would the observer see the sun overhead, or on the horizon?

ACTIVITY 7-8. Move the sun along the circle to a point where it would appear to be overhead to the observer. Then continue to move the sun to a point where it would appear to be on the horizon.



☐ **7-8.** How many degrees did you move the sun to make it appear overhead to the observer?

☐ **7-9.** How many degrees did you have to move the sun from its position in Activity 7-7 to make it appear to the observer that it moved from one horizon to the other?

Now think about what the observer would have seen with the earth turning, and the sun moving around the earth.

☐ **7-10.** In both cases, did the sun appear to the observer to move around the earth?

☐ **7-11.** In both cases, did the sun appear to the observer to rise from one horizon and set behind the other?

It isn't so easy to tell whether the earth is turning or the sun is actually moving around it. Either way the observer would see the sun move across the sky. Suppose the sun actually does move around the earth. Because it is far away (149 000 000 km) it would have to make a very long journey each day. It would have to travel very fast to make it in just 24 hours. You can get a good idea of the speed it must have to make the trip. You only need a few simple things. But you will have to have 30 minutes of sunlight.

EXCURSION

Excursion 7-1 is a good one for general interest and extension, and it provides some background on the calendar.

If you don't have 30 minutes left in this class, read ahead to see what has to be done. Then plan a time when you can do the activity. This would be a good time to do **Excursion 7-1,** "The Night That People Lost 10 Days." No equipment is needed.

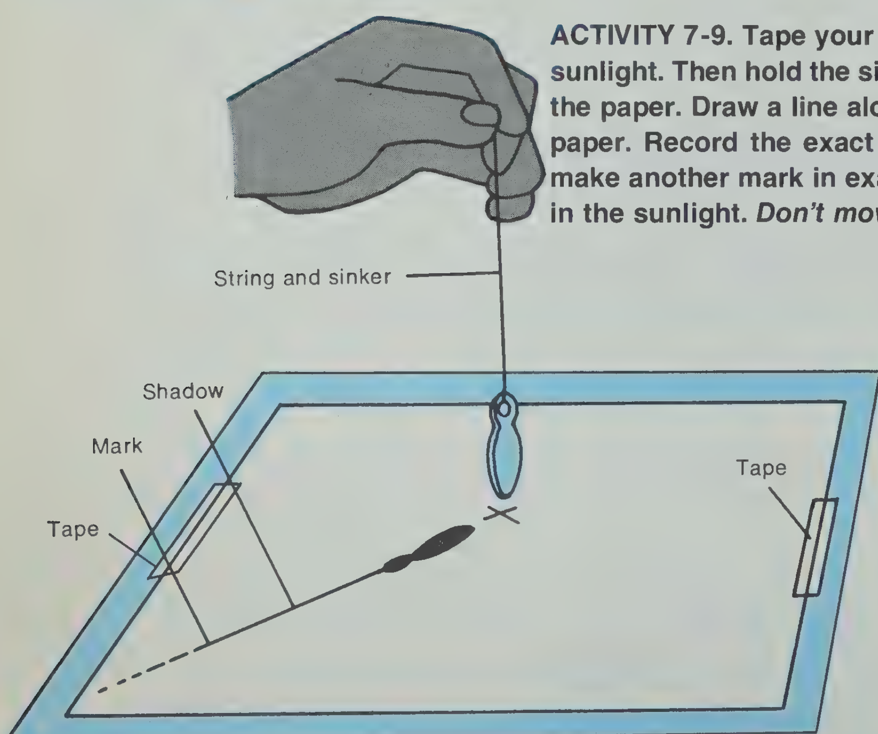
Got a sunny day and 30 minutes? Then find out how fast the sun would have to be to go around the earth each day. Get the following items:

1 lead sinker
1 50-cm piece of string
1 protractor
1 5-cm piece of masking tape or cellophane tape
1 sheet of white paper

Tie the string to the lead sinker. Make an X with your pencil in the center of the paper. Take everything outdoors or to a windowsill where the sunlight will fall for at least 30 minutes.

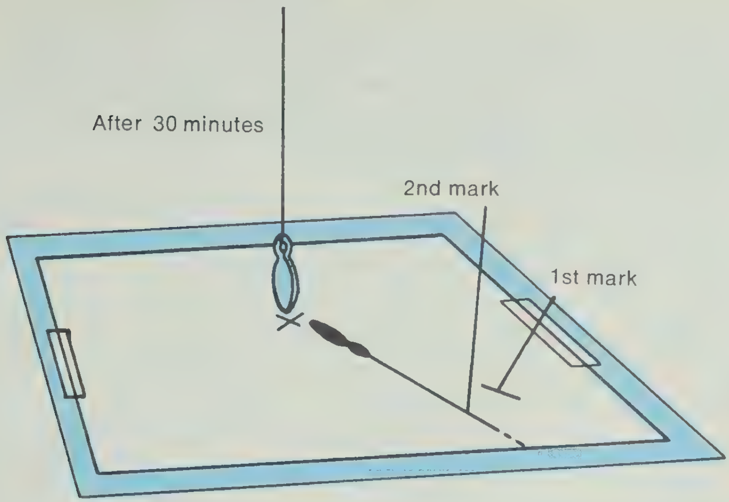
It may be possible for the student to use a ring stand or other vertical support from which to hang the sinker on the string. It could then remain motionless for the time period, and the beginning and ending positions could be marked.

ACTIVITY 7-9. Tape your paper to a flat surface that is in full sunlight. Then hold the sinker *exactly* over the X you drew on the paper. Draw a line along the shadow of the string on the paper. Record the exact time you make the mark. You will make another mark in exactly 30 minutes. Leave the surface in the sunlight. *Don't move it at all.*



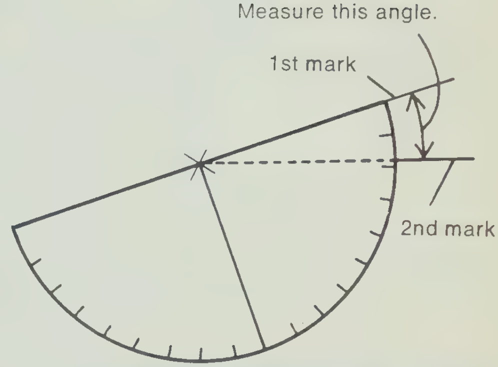
☐ **7-12.** At what time did you make your first mark?

ACTIVITY 7-10. ***Exactly*** **one half hour later, hold the string as you did before, and once again mark the shadow.**



☐ **7-13.** At what time did you make a second mark?

ACTIVITY 7-11. After you've made your second mark, take your paper back to your desk. With a ruler, draw straight lines from the X along each of the shadow marks. Measure the angle between the lines with a protractor.



☐ **7-14.** How many degrees are in the angle formed by the two shadow lines?

7-14. This answer (and some later ones that depend on it) may vary with geographic location, time of year, and time of day. An acceptable answer would be between 5° and 10°.

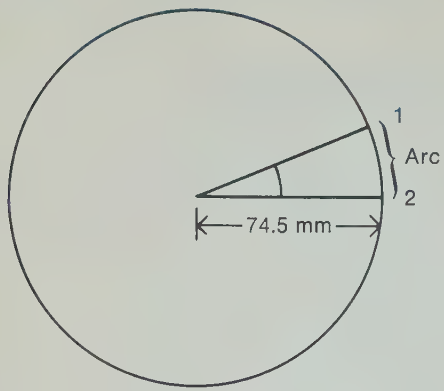
☐ **7-15.** How many degrees did the sun appear to move in 30 minutes?

Now try to apply what you have just done to the model you built earlier.

The sinker shadow acts like a sundial. It tells how fast the sun is moving across the sky. The position of the shadow moves as the sun moves. Measuring the distance the shadow moves in 30 minutes could tell you how fast the sun would have to move. Let's find out if it will.

The circle you used in Activities 7-2 through 7-8 had a radius of 74.5 mm. This size was chosen to make your next set of calculations easy. Think of a distance of 74.5 mm as representing half the distance of 149 million km from the earth to the sun.

If the apparent path of the sun were on the celestial equator every day instead of continually on a different path in the sky, then the shadow motion in one hour would be 15°. With this changing path across the sky, the apparent speed of the sun also changes during the different hours of the day. Thus, t angle measured in Activity 7-11 will affe the answers for questions 7-18, 7-19, 7-2 and 7-21.



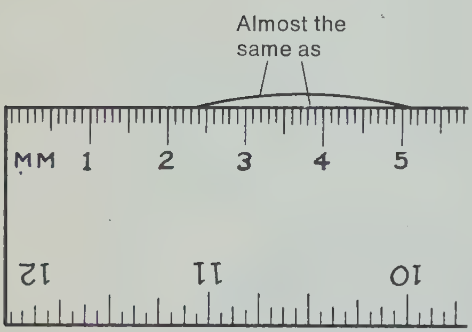
☐ **7-16.** How many km does each mm represent?

ACTIVITY 7-12. On the circle you used in Activities 7-2 through 7-8, draw an angle the same size as the one you measured in Activity 7-11. Use your protractor and a sharp pencil. The vertex of the angle is at the center of the circle. Label the points 1 and 2 as shown.

☐ **7-17.** The arc between 1 and 2 shows how far the sun appears to travel in what period of time?

Using the distance between 1 and 2, you can calculate how far the sun would have to travel in 30 minutes if it goes around the earth in one day.

You can't measure a curved line accurately with your ruler. But when the angle is small, the distance between two points along a curve is not too different from the distance along a straight line. This means that you can use a millimetre ruler to get a good estimate of the arc between 1 and 2. Use your ruler to measure it now.



☐ **7-18.** What is the distance in mm from point 1 to point 2 on your circle?

☐ **7-19.** Using the scale you determined in question 7-16, what is the distance in kilometres that the sun traveled in 30 minutes?

☐ **7-20.** If its speed is steady, how far would it travel in 1 hour?

☐ **7-21.** What would its speed in kilometres per hour have to be?

Your answer to question 7-21 should be a very large number. In fact, the speed is many, many times greater than that of any satellite ever put into orbit. And it is far greater than the calculated speed of other planets and most stars. Therefore, the idea that the sun moves around the earth each day is very unlikely.

☐ **7-22.** Can you think of a way to calculate how fast the earth is turning? (Hint: The distance around the earth is 40 000 km.)

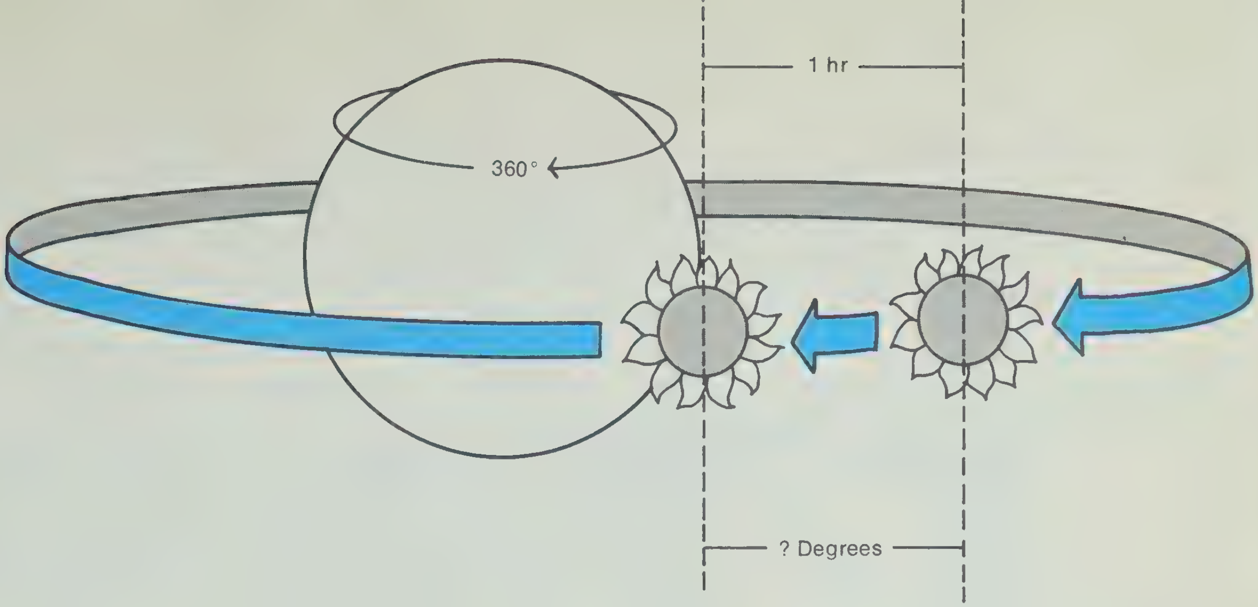
The statement is made that when the angle is small, you can use a ruler to measure the distance from 1 to 2 (measure the chord instead of the arc). For your information, for an angle of 15°, the arc is less than $\frac{1}{4}$ of 1% larger than the chord—an amount too small to detect with a ruler.

7-18. 16 mm to 32 mm
7-19. 16 000 000 km to 32 000 000 km
7-20. 32 000 000 km to 64 000 000 km
7-21. 32 000 000 kph to 64 000 000 kph

As a comparison, the orbital speed of Mercury, which is the fastest traveling planet, is about 170 000 km per hour. Fastest orbital speed for a satellite in circular orbit around the earth is about 27 000 km per hour. Both of these speeds are tiny compared with the calculated speed of the sun.

7-22. The speed of a point on the equator is about 40 000 km in 24 hours, or slightly more than 1600 km per hour.

If the earth turns through 360° in 24 hours, then it turns 15° per hour. This is the average number of degrees the sun appears to travel in an hour. The students' answers should indicate that the time zones, one hour in difference, are roughly 15° in width. The continental U. S. is about 60° across (67° W latitude to 125° W latitude) and there are 4 time zones: Eastern, Central, Mountain, an Pacific. Each is approximately 15° wide, a though the width varies somewhat to ac commodate state boundaries.



PROBLEM BREAK 7-1

You know that the apparent rising and setting of the sun is caused by the earth's making one complete turn on its axis in 24 hours. You know that there are 360 degrees in a circle, or in one turn of the earth. Using this information, you can figure the number of degrees that the sun appears to travel in one hour.

What is the relationship between the number of degrees that the sun travels in one hour and the time zones that we use? For example, why is the time in New York different from the time in Chicago, and the time in Denver different from the time in Los Angeles? Write your explanation in your Record Book.

You have seen that your daily observations of the sun do not tell you whether it, or the earth, is moving around the other. Because you've been told, you know that the earth turns. The movement of the sun must be just an illusion. Even so, it is more comfortable to say the sun "rises" or "sets" than to say the earth is turning. It feels quite natural to say the sun moves across the sky.

You can see why many scientists of old thought people lived in a sun-centered system. You can also see why others claimed that the universe was earth-centered. To find out how Galileo resolved this debate, do **Excursion 7-2**, "Matching Wits with Galileo."

Before going on, do Self-Evaluation 7 in your Record Book.

Excursion 7-2 is for extension and general interest and lets the student follow Galileo's logic in solving the problem of the model of the solar system.

No advance preparations need to be made for Chapter 8.

EXCURSION

EQUIPMENT

None

Excursion 7-1

The Night That People Lost 10 Days

PURPOSE

To explain how the present calendar came into being, and to tell some of the changes that had to be made in order to use it.

This is an excursion for general interest and extension.

MAJOR POINTS

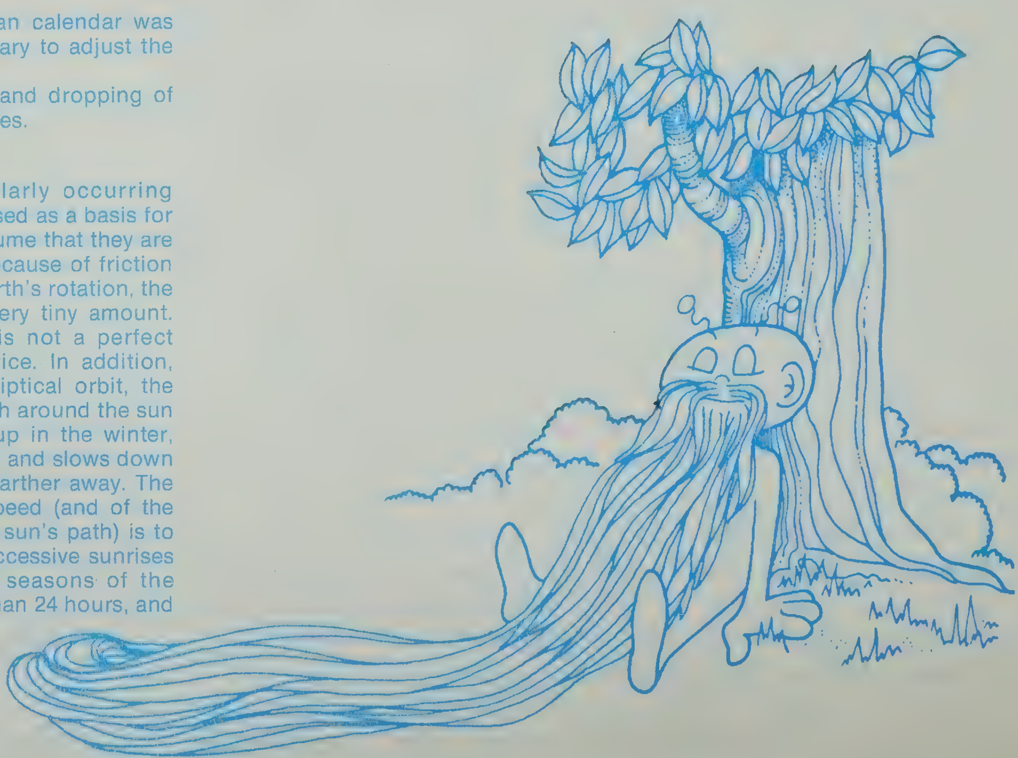
1. A calendar is a system of timekeeping based on some regular events.
2. Three possible regular events are the appearance of a full moon, a sunrise, or the coming of spring.
3. Probably the first calendar was made more than 4000 years ago.
4. The Romans made significant changes in the calendar.
5. A church decree setting the time for the celebration of Easter as the first Sunday on or after the first full moon after the first day of spring necessitated further changes in the calendar.
6. When the new Gregorian calendar was adopted, it became necessary to adjust the date accordingly.
7. The changing of dates and dropping of days caused many difficulties.

Although the three regularly occurring events listed here can be used as a basis for a calendar, you cannot assume that they are not subject to variation. Because of friction of the tidal forces on the earth's rotation, the earth is slowing down a very tiny amount. Thus, the rotating earth is not a perfect clock, or timekeeping device. In addition, because of the slightly elliptical orbit, the speed of the earth in its path around the sun is not uniform. It speeds up in the winter, when it is closer to the sun, and slows down in the summer, when it is farther away. The effect of this change in speed (and of the obliquity of the ecliptic, or sun's path) is to make the time between successive sunrises different in the different seasons of the year—sometimes greater than 24 hours, and sometimes less.

You've probably heard the story of Rip Van Winkle, who slept for 20 years. But have you heard about the night the people of Rome, Italy, actually slept away 10 days? It seems incredible, but in 1582 everybody in Rome went to bed on October 4 and woke up on October 15. Even more remarkable is the fact that the next day, October 15 in Rome, was only October 5 in London, England! How this amazing turn of events came about is the subject of this excursion.

The story goes back a long way—to a time well before the birth of Christ. In those early days, people used natural events to mark the passage of time. Such things as the arrival of certain birds or temperature change measured the time of year. Of course, these methods were not completely satisfactory. Bird arrivals and temperature changes don't happen at exactly the same time each year.

To solve this problem people had to develop a calendar. That is a system of timekeeping based on some regularly occurring event. They found that at least three such events could be used.



1. The time from one full moon to the next
2. The time from one sunrise to the next
3. The time from one spring to the next (Astronomers determined the first day of spring. They did this by observing the exact time the sun passed a particular point in the sky on its north-south journey.)

EARLY CALENDARS

The Sumerians lived more than 4000 years ago in what is now Iraq. They were probably the first people to make a calendar. They used the phases of the moon to determine how long a month was (about 30 days). In the Sumerian calendar, twelve lunar months (360 days) made a year.

☐ **1.** How may days shorter than our year was the Sumerian year?

The Sumerians had to make up the difference between their year and the amount of time that passed between springs. They did this by adding an extra month about every fourth year.

The particular point in the sky that is used to determine the first day of spring changes also. The earth, spinning on its axis as it revolves around the sun, wobbles somewhat like a giant top. This means that the North Pole points at a different spot in the heavens, and the place where the apparent path of the sun crosses the celestial equator, called the equinox, moves a little also. During a lifetime the motion is extremely small, but in the 2000 years since man began using a reference point in the sky, it has shifted about 30°. In the time of Hipparchus (130 B.C.) the point locating the first day of spring was in the constellation of Aries, the Ram. Now it is located a whole constellation away, in Pisces, the Fishes. But astronomers can still locate its exact position each year.

☐ **2.** About how often should the Sumerians have added a 30-day month to get a year as long as ours?

The lunar month, from full moon to full moon, is a little over $29\frac{1}{2}$ days long. The Islamic calender, still in use in Moslem countries, is based on the lunar cycle, and the first day of spring changes in an erratic fashion from year to year.

But there were problems with this calendar. The Sumerians were never able to adjust their calendar so that the seasons arrived in exactly the same month each year. The Greeks, the Hebrews, and the Egyptians made improvements in the Sumerian calendar. But the problem continued.

The calendar of the early Romans was also based on the phases of the moon. The Roman year was 355 days long. The months that corresponded to our March, May, July, and October were 31 days long. February had 28 days, and each of the other seven months had 29 days. The Romans, like the Sumerians, added an extra month every fourth year.

The word *calendar* comes from the Latin word *kalendae*—the first of the Roman month. On this day accounts were entered in an account book (*kalendarium*) and paid. Paying bills on the first of the month obviously goes back a long way.

The Roman high priest kept track of the calendar. On each *calends,* or day of the new moon, the priest announced the phases of the moon for that month. The first quarter phase was called the *nones*. The full moon was the *ides*.

3. By the information given here, the ides are the time of the full moon, so the answer would be "the date of the full moon in March." However, it is more commonly accepted that in the ancient Roman calendar, the ides of March, May, July, and October were on the 15th of these months. In other months, the date was the 13th. Likewise, the nones were the 9th day before the ides.

☐ **3.** You may have heard the famous quote from Shakespeare's *Julius Caesar:* "Beware the ides of March." What is meant by the ides of March?

JULIUS CAESAR'S CALENDAR

By 46 B.C., the Roman emperor Julius Caesar had become unhappy with the Roman calendar. Because the priests had done a poor job of keeping the calendar, the summer months were coming in spring. To solve the problem, Caesar introduced what became known as the Julian calendar.

The Julian calendar was devised by the Egyption astronomer Sosigenes. It has a 365-day year (10 days longer than the Roman calendar). The extra 10 days were added to the months with 29 days, making them identical with the months on today's calendar.

The unique feature of the Julian calendar was the extra day added to every fourth (or leap) year. This produced the same result that adding a quarter of a day to each year would produce. In effect, this meant that the Julian year was $365\frac{1}{4}$ days long. This is almost, but not exactly, as long as the earth takes to make a complete turn around the sun. The Julian year was only a few minutes per year longer than the earth year. Therefore the change of seasons occurred on almost the same date every year.

Without leap years, after 750 years January would be the middle of summer in the Northern Hemisphere, and July would be a cold month.

We would probably be using the Julian calendar today if it were not for something that happened in A.D. 325. That year there was an important meeting of church officials in Nicaea (what is now Turkey). At the Council of Nicaea, the bishops decided that Easter would be celebrated on the first Sunday after the first full moon that occurs on or after the first day of spring. In A.D. 325 the first day of spring occurred on March 21. This meant that Easter could not occur before March 22 or after April 25.

The rule for the determination of the date for Easter is still the same. Thus, between A.D. 1800 and A.D. 2000 the celebration falls on all the dates from March 22 to April 25.

4. If students have difficulty with this question, encourage them to concentrate on the extremes—that is, on March 22 and April 25. If March 21 came on Saturday and there was a full moon that day, then the first Sunday after the first full moon on or after March 21 would be March 22. If March 21 came on Sunday and there was a full moon the day before, March 20, then the next full moon would be a lunar month later, ($29\frac{1}{2}$ days) on Sunday, April 18, and the first Sunday after that is April 25.

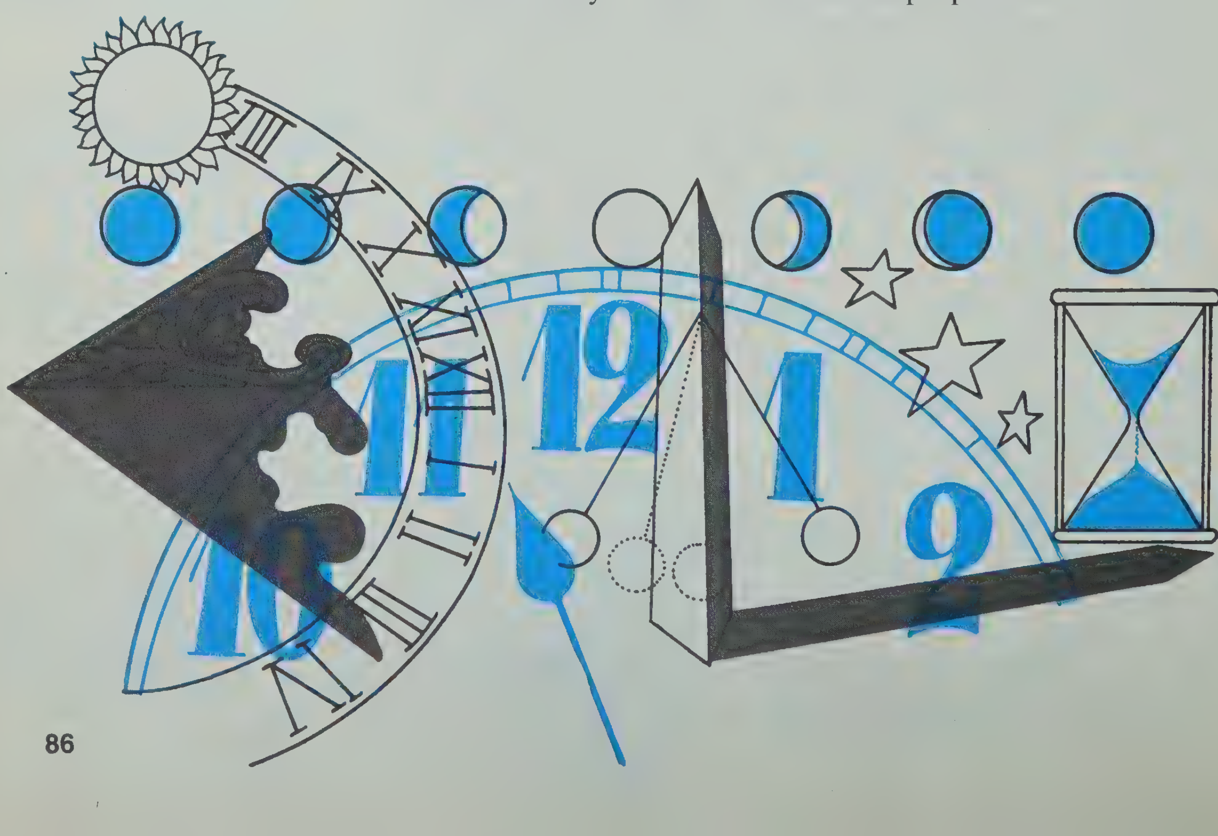
The difference in time mentioned here was about 11 minutes per year. That amounts to 8 days in 1000 years. From A.D. 325 to A.D. 1562 (1237 years) it came to 10 days.

Actually, the Gregorian rule states that only the century-ending years that are divisible by 400 should be leap years. Thus, the years 1800, 1900, and 2100 have no February 29, but the year 2000 does have the extra day. This puts the calendar remarkably close to the ordinary year. The difference is less than half a minute, and the calendar will get out of step only one day every 3000 years.

☐ **4.** See if you can explain why Easter would have to occur within these dates in order to meet the council requirements.

Over the years the difference between the time it takes the earth to go around the sun and the $365\frac{1}{4}$ days in the Julian calendar began to add up. In fact, by the year 1562 it added up to 10 full days. That year the first day of spring came on March 11 instead of March 21! This meant that Easter would be celebrated at a time before March 22. This violated the rules of the Church.

Pope Gregory decided to change the calendar to make sure that Easter would be celebrated at the proper time. This decision led to the 10-day sleep mentioned at the beginning of this excursion. The pope decreed that the day following October 4, 1582, would be October 15. He also directed that, in the future, leap year would be omitted about once every 128 years. (This made the calendar year almost exactly the same length as the earth year.) The dropping of the specified leap years was designed to keep the first day of spring on the same date. In that way, Easter would always be celebrated at the proper time.



THE GREGORIAN CALENDAR

The new calendar proclaimed by Pope Gregory became known as the Gregorian calendar. The Gregorian calendar set January 1 as the beginning of the year. Until then, the year had begun in some countries on December 25, in others on January 1, and in still others on March 25.

The Gregorian calendar was adopted immediately by countries with large Catholic populations. Protestant countries, and some countries in the Middle East, continued to use the Julian calendar. For example, the new calendar was not adopted in England until 1752. By this time, the English had to drop 11 days, not 10. Many English resented the change and held protest marches, crying "Give us back our 11 days." Most Middle Eastern countries didn't adopt the Gregorian calendar until 1923. These countries had to drop 13 days. The Chinese adopted the new calendar in 1912.

☐ **5.** Can you explain why it was October 15 in Rome and only October 5 in London following Pope Gregory's decree?

The argument over which calendar to use has caused trouble for people who study history. Historical dates depend upon what book you read. For example, George Washington was born either on February 22, 1732, or on February 11, 1731. The difference depends upon whether or not the writer dropped the 11 days. And it depends upon whether he considered the year as starting on January 1 or on March 1. In fact, some books list Washington's birthday as February $\frac{11}{22}$, $173\frac{1}{2}$.

The Pilgrims landed at Plymouth, Massachusetts, on December $\frac{11}{21}$, 1620. According to Governor William Bradford, they began building their first house on December 25, 1620. By the Gregorian calendar, however, this was January 4, 1621.

Changing the calendar has caused legal problems, too. Some landowners in England tried to collect rent on their property for the 11 days that were dropped from the calendar during 1752. The British Parliament had to pass a special act declaring that salaries, rents, and interest would not be collectable for the 11 lost days.

Excursion 7-2
Matching Wits with Galileo

EQUIPMENT

None

PURPOSE

To examine the logic used in deciding between the Ptolemaic and Copernican models of the solar system.

This is a general-interest and extension excursion.

MAJOR POINTS

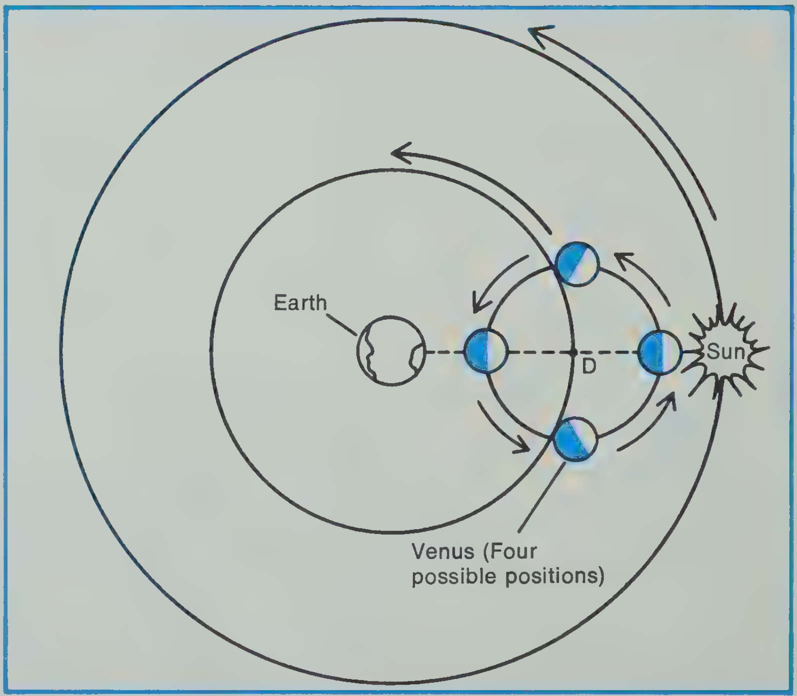
1. In the model of the solar system propounded by Ptolemy, the earth was at the center of the system.
2. Ptolemy believed Venus and the sun moved so that a straight line could always connect the earth, the sun, and the center of Venus's epicycle.
3. Copernicus proposed a model with the sun at the center of the system, and the planets revolving around it.
4. As observed with a telescope, Venus passes through phases much as our moon does. However, it also changes in size, more than the moon does.
5. The change in shape and size of Venus supports the Copernican model of the solar system.

For your information, but not important for the student, is the fact that in the Ptolemaic system, point D in its successive positions is called a deferent. As you can see from Figure 1, a view of Venus from the earth, with the sun always farther away, could never show anything more than a thin crescent.

According to the theory of Ptolemy, an ancient Greek astronomer, the earth is at the center of the solar system. In other words, the planets and the sun move around the earth (see Figure 1). Ptolemy's theory holds that Venus is closer to the earth than is the sun. The theory also holds that as Venus travels around the earth, it moves in another circular path. Figure 1 shows this as a motion around point D.

Ptolemy also believed Venus and the sun move in a special way. The motion allows a straight line to be drawn joining the earth, the sun, and point D.

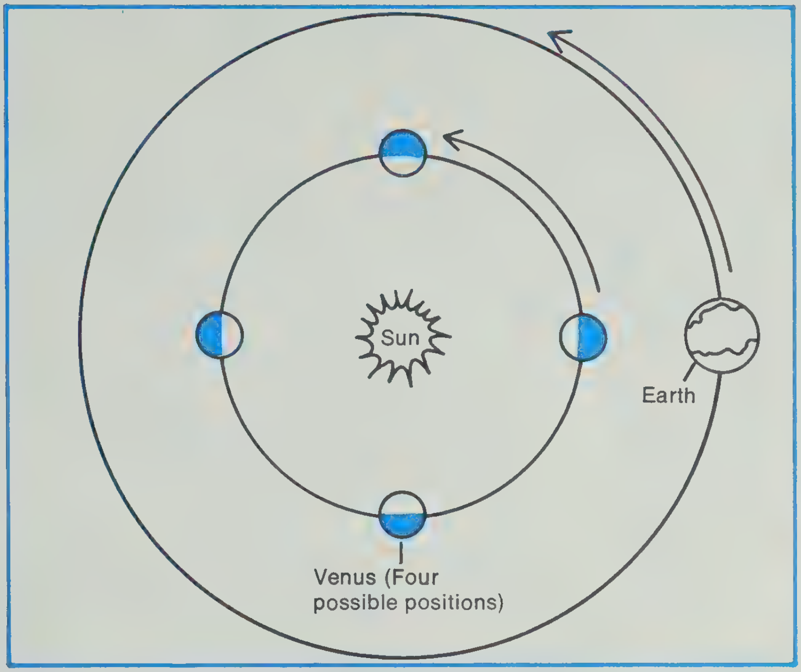
Figure 1



Copernicus believed the sun is at the center of the solar system. He believed Venus and the earth (and the other planets as well) move around the sun (see Figure 2).

A view of Venus from the earth in the Copernican model (Figure 2) should show phases of the planet, all the way from no light (a "new Venus") to a full orb of light (a "full Venus"). Moreover, because of the large change in distance between the earth and Venus in this model, there should be a distinct change in the size of the planet's image.

Figure 2



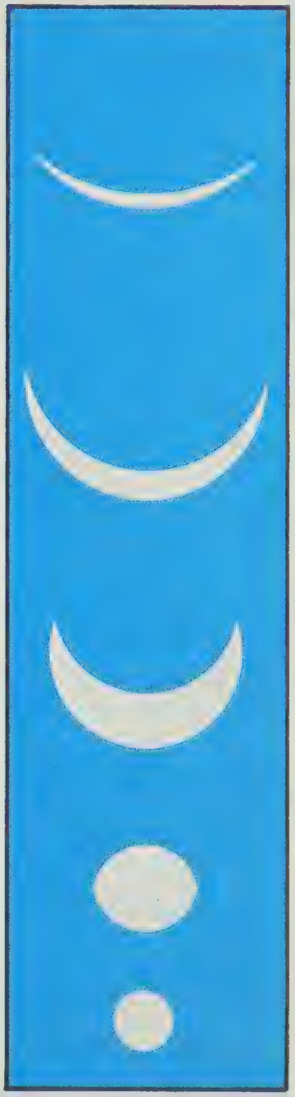


Figure 3

Galileo tried to decide which of the two theories was correct. With a telescope that he made, he observed Venus for two years. He observed some interesting changes in the appearance of the planet. What he saw is shown in Figure 3. He found that the shape of Venus changed, very much as the shape of our moon seems to change. Galileo realized that he had all the information he needed to decide definitely whether Ptolemy or Copernicus was right. You have all the information that you need, too. Match wits with Galileo. On the basis of the telescope evidence and Figures 1 and 2, tell which theory you support and why.

☐ **1.** Which theory do you support?

☐ **2.** What are your reasons for supporting the theory?

Hopefully, the student will choose the Copernican model. The change in shape will be the more likely reason for support, but the change in size is of equal importance. Together they form a strong case.

On Your Own

8

EQUIPMENT

None

CHAPTER EMPHASIS

The students finally use data and techniques gathered in Chapter 3, with the distance to the sun in Chapter 5, to find the sun's power. Students then use techniques from other chapters to solve some individual problems in astronomy.

Excursion 8-1 is keyed to this chapter.

At the beginning of this module, you set out to investigate the way astronomers get information about stars and planets. You now should have a pretty good idea of the way astronomers work. By using sun-energy measurers (pyrheliometers) and photographs of spectra and by calculating angles, they can make quite remarkable measurements.

Several questions were asked at the beginning of Chapter 1. These questions appear again below. See if you can answer them now. You may want to compare your new answers with the ones you gave before. Here are the questions.

☐ **8-1.** How do astronomers know what the sun is made of?

☐ **8-2.** How can you find out how much energy the sun gives off each minute?

☐ **8-3.** How can the distance to the sun be determined?

☐ **8-4.** How can the size of the sun be determined?

☐ **8-5.** How can the motion of the sun be described?

Question 8-2 is one that has not been answered completely. You have found that the sun can be compared with a known source—like a 150-watt bulb. And you found that distance to a light source has a lot to do with measuring its energy. But the relationship between the sun's energy and the energy of a 150-watt bulb is certainly not obvious. Let's think about it just a bit more.

MAJOR POINTS

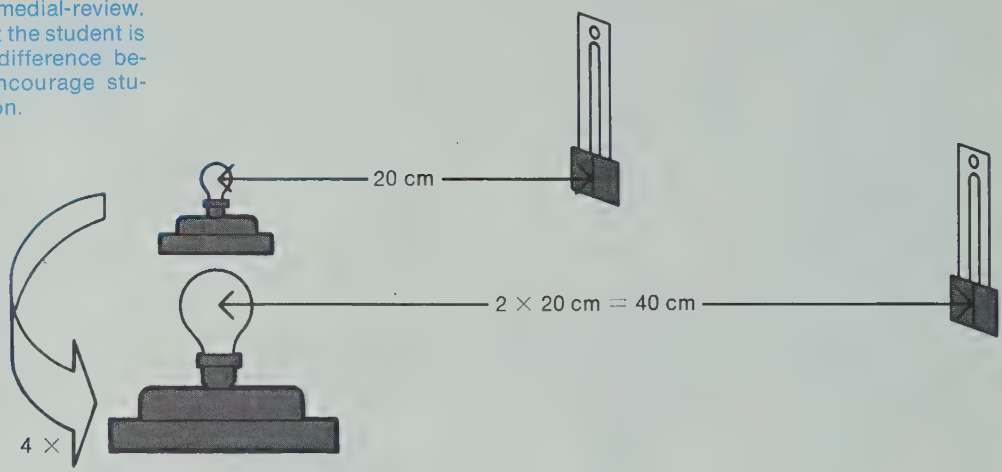
1. The power of the sun at a distance of 149 million km can be compared with the power of a light bulb at a short distance.
2. The power required to produce a particular heating effect on an object must be 4 times as much when the distance from the power source to the object is doubled.
3. If power varies as the square of the distance, then the power of the sun can be computed in terms of a 150-watt bulb.
4. The power (wattage) of the sun is a huge number.
5. Using observed spectra and pyrheliometer readings, and given the distances to stars, comparisons can be made of their power and composition.
9. Astronomers use other tools besides telescopes.

This chapter calls for application by the student of the various concepts encountered during the unit. Due to the lack of equipment usage and experimental activities, there is a danger that the work will be taken too lightly, and rapidly passed over. Guard against this. The chapter can be the "frosting on the cake."

☐ **8-6.** Would the heat from a 150-watt bulb warm up your sun-energy measurer if the bulb were 149 million km away?

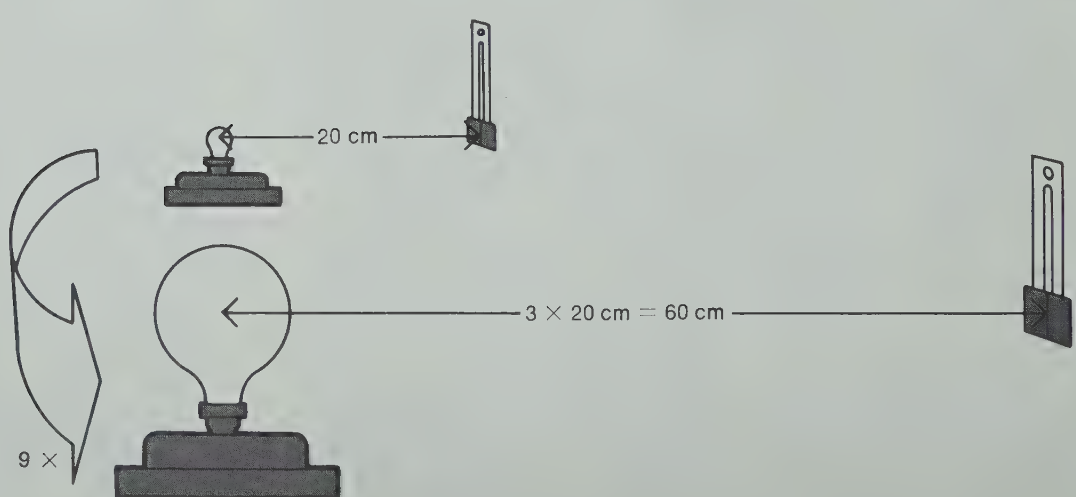
Before going on, be sure you know what power is. **Excursion 8-1,** "Power," will help.

Excursion 8-1, "Power," is remedial-review. This is really the first place that the student is expected to understand the difference between energy and power. Encourage students to do the short excursion.



Here's what scientists have discovered. You could do it yourself, too.

Suppose the distance from an object to a light source is doubled. Then the light source must be 4 times as powerful for the same amount of light to reach the object.



If the distance to the source is tripled, the source has to be 9 times as powerful.

Table 8-1 shows more about how distance to the source relates to the power the source must have.

Table 8-1

If the original distance from source to object is multiplied by	Then the original power of the source must be multiplied by
2	4
3	9
4	16
10	100
50	2500
100	10 000
1000	1 000 000

☐ **8-7.** The numbers in Table 8-1 have a very interesting relationship. What do you think that relationship is?

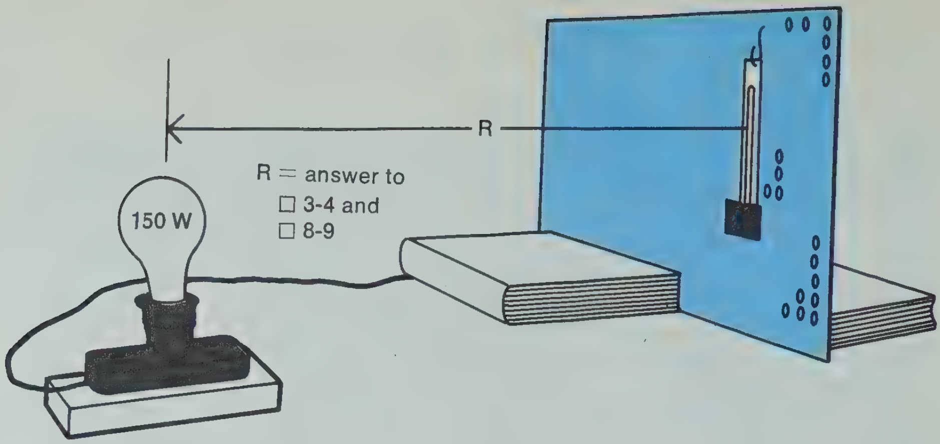
Notice the numbers in column 1, the distance multipliers. In each case, when one of those numbers is multiplied by itself (squared), it gives the power multiplier associated with it (in column 2). Thus:

$$2 \times 2 = 4$$
$$3 \times 3 = 9$$
$$50 \times 50 = 2500 \text{ etc.}$$

☐ **8-8.** Suppose the original distance is multiplied by 10 000. What do you predict the power multiplier to be?

Now let's get back to comparing the 150-watt bulb with the sun.

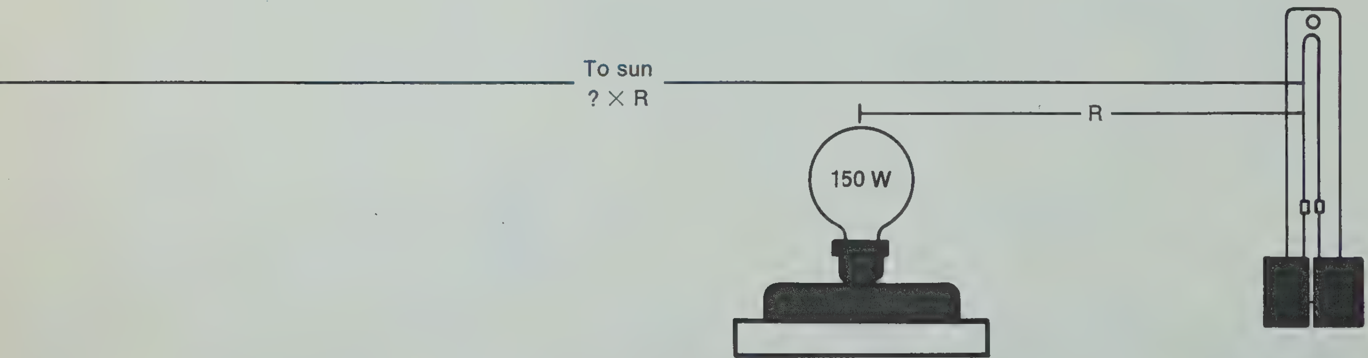
In Chapter 3 you compared a 150-watt bulb with the sun. You found out how far the bulb had to be placed from the sun-energy measurer to give the same temperature change as direct sunlight. Your finding was the answer to question 3-4.



Question 8-9 refers the student to question 3-4 for an answer. This is just one example of the need to use all the preceding chapters in working on this one. Be prepared to supply the value needed in case the student failed to answer question 3-4.

☐ **8-9.** What is the distance in cm you found for the position of the 150-watt bulb?

R is the distance you found for the 150-watt bulb. Of course the distance to the sun is 149 million km. How many times greater is 149 000 000 km than R? There are 100 000 cm in 1 km.



☐ **8-10.** How many cm are there in 149 000 000 km?

☐ **8-11.** Now divide your answer to question 8-10 by R. (The result will be the number of times R must be multiplied to give you the distance to the sun.) Record this number in the last row of Table 8-1 as a distance multiplier.

You are about ready to find out how much power the sun has as measured in watts. You will multiply 150-watts by the power multiplier.

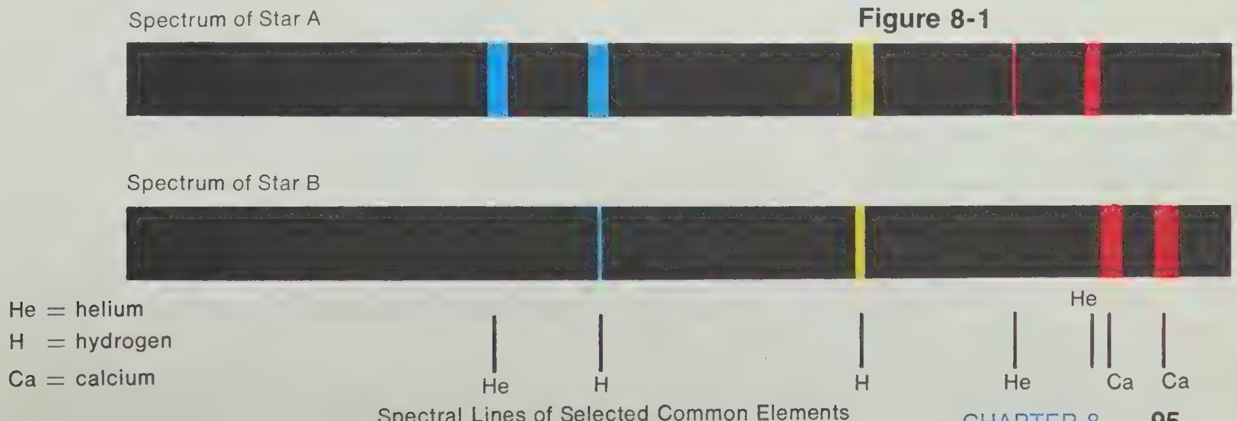
☐ **8-12.** What is the power multiplier that goes with the distance multiplier you recorded in Table 8-1? Record your answer in Table 8-1.

☐ **8-13.** What is the sun's energy measured in watts? (150 watts × power multiplier)

8-13. The actual figure the student gets is not too important, but, for your information, the sun's power is about 370 000 000 000 000 000 000 000 000 watts (that's 3.7×10^{26} W).

Now you can test your ability to use some of the other techniques you have learned. You will be given spectroscope data for two stars, Star A and Star B. Your task is to interpret this information to find out as much as you can about the stars. From it, you should be able to compare the two stars in composition, distance, and power.

Figure 8-1



The major star nearest to our solar system is about 40 000 000 000 000 km away, which matches the distance to Star B. It is the triple star Alpha Centauri. Star A just about matches in distance Sirius, the brightest star in the sky.

The pyrheliometer would of course have to be mounted at the focus of a large telescope in order to get any energy readings.

From the spectra, the student should conclude that Star A contains the elements helium and hydrogen, and Star B contains hydrogen and calcium. From the distance and energy data, students should conclude that Star A is twice as far away as Star B, that the energy received from Star B is about twice as much as that from Star A, and that therefore the power of Star A is greater than that of Star B. If the two stars had the same power, Star A would have produced only $\frac{1}{4}$ as much temperature change as Star B, since Star A is twice as far away. Instead, it produced $\frac{1}{2}$ as much; so Star A must be greater in power.

It will probably come as no surprise to you that there are very few astronomers who spend much time looking through big telescopes. Instrumentation and photographic techniques have made great changes in the art of astronomy.

Table 8-2

Star	Distance from the Earth
A	80 000 000 000 000 km, or 8 000 000 000 000 000 000 cm
B	40 000 000 000 000 km, or 4 000 000 000 000 000 000 cm

Table 8-3

Energy Data	Sun-energy measurer reading
Star A	19.9 °C
Star B	34.6 °C
Reading in shade	5.2 °C

Figure 8-1 shows the spectra observed when the light from Star A and Star B passed through a spectroscope. It also shows the Fraunhofer spectral lines of some common elements. Look at the spectra carefully. They and Tables 8-2 and 8-3 contain all the information you need to finish this chapter. A review of Chapters 1, 2, and 3 may help in analyzing these data.

☐ **8-14.** According to the spectra, how do the chemical compositions of the stars compare?

☐ **8-15.** How much farther away is Star A than Star B?

☐ **8-16.** How does the energy of Star A compare with that of Star B?

Most people think of astronomers as constantly looking through big telescopes. But the telescope is by no means the astronomer's only tool. In recent years, new ways of studying the heavens have been used. Not long ago, for example, it was discovered that some stars and groups of stars give off radio waves. By studying these waves, radio astronomers are locating objects that were unknown only a few years ago.

If you've done your work well, you now realize that a lot of work involves only a pencil, a piece of paper, and, most importantly, a lot of hard thinking. Of course, a computer comes in handy.

Before going on, do Self-Evaluation 8 in your Record Book.

Excursion 8-1
Power

EQUIPMENT

None

PURPOSE

To explain the difference between energy and power.

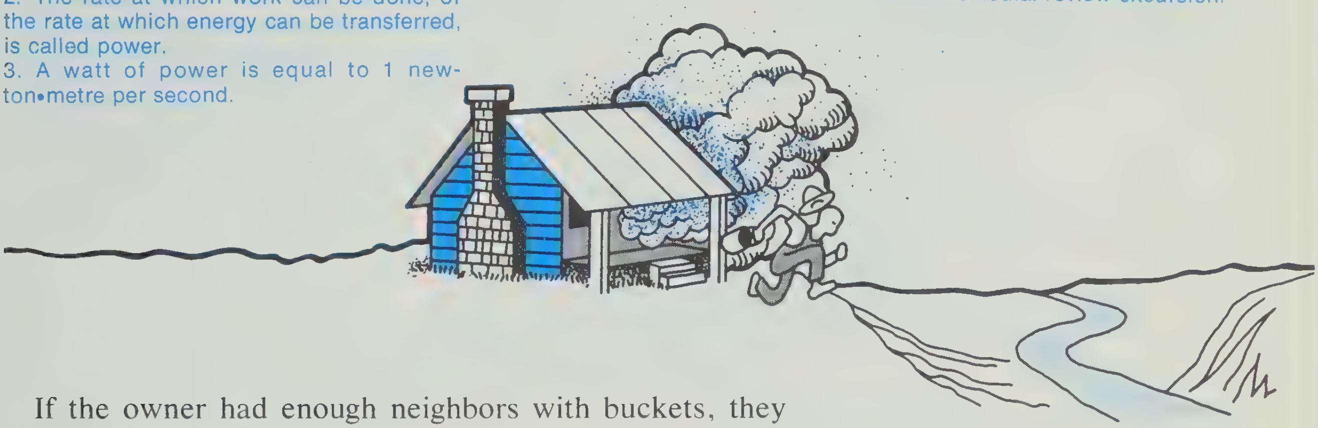
This is a remedial-review excursion.

Suppose a house stands on a hill beside a river. The house catches on fire. Naturally, the owner would like to get water from the river and put out the fire. If there was no help, the owner could try to run back and forth with one or two buckets, carrying water to throw on the fire. But if the fire has a head start, the house would be lost.

MAJOR POINTS

1. The time it takes to do a given amount of work is important.
2. The rate at which work can be done, or the rate at which energy can be transferred, is called power.
3. A watt of power is equal to 1 newton•metre per second.

Figure 1

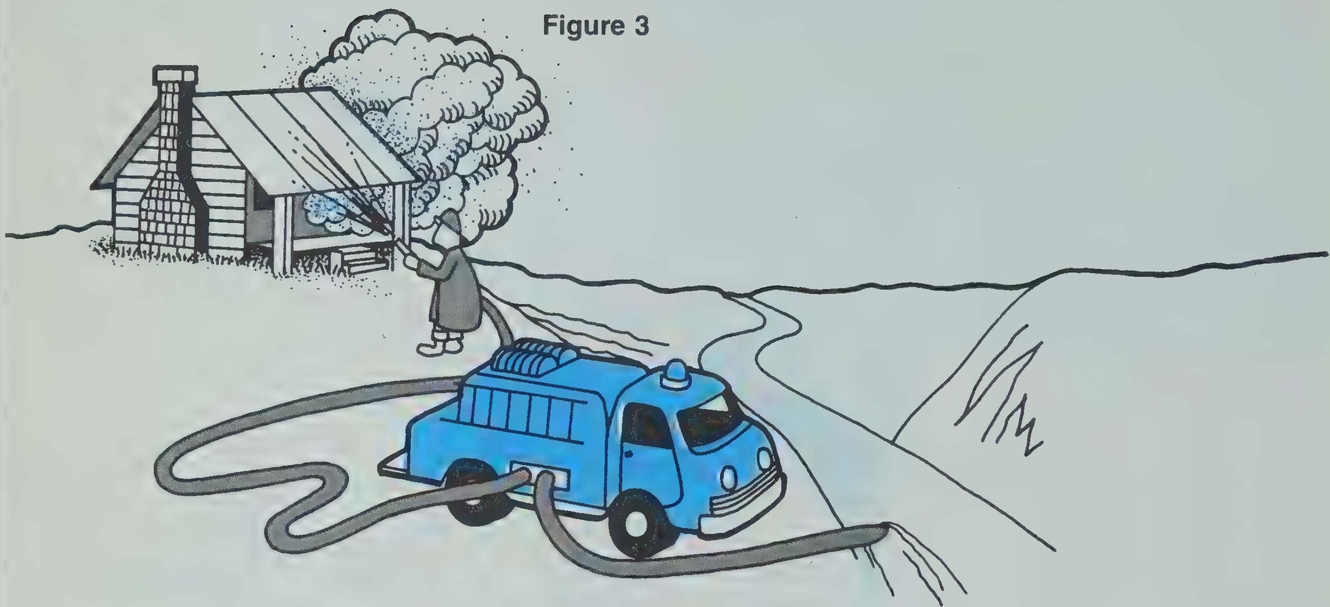


If the owner had enough neighbors with buckets, they could form a double line. They could hand full buckets up and empty buckets down. Certainly more water could be carried to the house each minute this way. The chance of saving the house would be a great deal better.

Figure 2

If a fire truck with a powerful pump and a long hose came along, it would be even better. More water per minute could be transferred from the river to the house.

Figure 3



What is the point of the story? Just this: Almost always, the time it takes to do a given amount of work is quite important. Given a long enough time, the owner could have carried any amount of water from the river to the house. But after the house has burned down, the water does no good.

In the language of science, the *rate at which work can be done (rate at which energy can be transferred),* is almost always very important. There is a real difference between a person with a bucket and a fire truck with a pump. That difference is the rate at which each can do work.

Science has given a name to the rate of doing work, or the rate of energy transfer. The name is *power*.

The power of the sun is the amount of energy per second it sends out into space. This power can be measured in units called watts. Perhaps you recall the definition of a watt.

$$1 \text{ watt} = \frac{1 \text{ newton}\cdot\text{metre}}{\text{second}}$$

Remember, calculating the wattage of the sun means calculating the energy it produces per second.

If the student still has trouble understanding the concept of power, it is conceivable that the difficulty lies in an inadequate knowledge of energy. You may want to suggest repeating Excursion 2-1, "Energy at Work."

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EQUIPMENT

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In Orbit

Record Book

THE NATURAL WORLD MODULES/LEVEL 3

PROGRAM DIRECTORS

Ernest Burkman THE FLORIDA STATE UNIVERSITY
Stewart P. Darrow THE FLORIDA STATE UNIVERSITY
David D. Redfield THE FLORIDA STATE UNIVERSITY
William R. Snyder THE FLORIDA STATE UNIVERSITY

SILVER BURDETT COMPANY
Morristown, New Jersey • Glenview, Ill. • Palo Alto • Dallas • Atlanta

PROGRAM CONSULTANTS

Joseph Agresta	COLONIA JUNIOR HIGH SCHOOL, WOODBRIDGE, NEW JERSEY
Thomas Atkinson	STATE UNIVERSITY OF NEW YORK AT ALBANY
Thomas Boehm	STATE UNIVERSITY OF NEW YORK AT ALBANY
Sarah Craig	FLORIDA STATE UNIVERSITY
Francis Chenoweth	SCHROP JUNIOR HIGH SCHOOL, AKRON, OHIO
Richard Daume	PARKWAY EAST JUNIOR HIGH SCHOOL, CREVE COEUR, MISSOURI
Frederick Johnson	SHELBY COUNTY BOARD OF EDUCATION, MEMPHIS, TENNESSEE
Mable Lund	MOUNTAIN VIEW JUNIOR HIGH SCHOOL, BEAVERTON, OREGON
Joan Powell	EAST JUNIOR HIGH SCHOOL, WEST CHESTER, PENNSYLVANIA
Charles Richardson	BELZER JUNIOR HIGH SCHOOL, INDIANAPOLIS, INDIANA
Clarence Trentlage	FREEDOM HIGH SCHOOL, FREEDOM, WISCONSIN

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Contents

To the Student

This Record Book is where you should write your answers. Try to fill in the answer to each question as you come to it. If the lines are not long enough for your answers, use the margin, too.

Fill in the blank tables with the data from your experiments. And use the grids to plot your graphs. Naturally, the answers depend on what has come before in the particular chapter or excursion. Do your reading in the textbook and use this book only for writing down your answers.

Toward the end of this Record Book, you will find a set of Self-Evaluations for each chapter. Do these to check your progress. To check your answers to the Self-Evaluations, turn to the Self-Evaluation Answer Key in the back of this Record Book.

Answers provided are often completely dependent on local circumstances. Be quite flexible as you assist your students with their attempts to answer questions. Answers are hardly ever as important as the process that generates them.

Chapter 1
The Message of Sunlight

☐ **1-1.** How do astronomers know what the sun is made of?

Answers will vary. Don't expect too much for 1-1 through 1-5. Students will get another opportunity to answer these questions in Chapter 8.

☐ **1-2.** How can you find out how much energy the sun gives off each minute?

☐ **1-3.** How can the distance to the sun be determined?

☐ **1-4.** How can the size of the sun be determined?

☐ **1-5.** How can the motion of the sun be described?

☐ **1-6.** List the colors of the spectrum of sunlight. Put them in order.

Violet, blue, green, yellow, orange, red

☐ **1-7.** Compare the number and order of your list of colors with those in Figure 1-1.

Same; or exactly opposite

☐ **1-8.** Which causes the spectrum to appear, the plastic disk or the slit? How do you know?

Plastic disk; the disk alone in the spectroscope will produce a round, spread-out spectrum; the slit alone produces nothing.

☐ **1-9.** Describe what you did to get your answer to question 1-8.

Answers will vary. Most likely answer is that the student tried each end separately on the tube to see which produces the spectrum.

☐ **1-10.** In the space provided, write the colors produced by the bulb. List the colors in the order you see them in the spectrum. If you find any differences between this spectrum and the one produced by sunlight, list them. See if certain colors show up strongly. Are there any bright or dark lines?

Violet, blue, green, yellow, orange, red (or reverse order) (No major difference between spectra is an acceptable answer. Students may see dark lines in sun's spectrum.)

☐ **1-11.** Next, use your spectroscope to examine the light from a fluorescent tube. Again, list the colors in the spectrum as you see them. Also, describe any differences between the spectra from the fluorescent tube and the one from sunlight.

Violet, blue, green, yellow, orange, red (or reverse order) (Students should notice pronounced bright lines against a continuous spectrum background.)

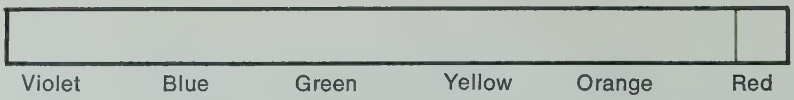
☐ **1-12.** Compare the spectrum of the alcohol lamp with the spectrum of sunlight.

Spectrum is too faint to be seen.

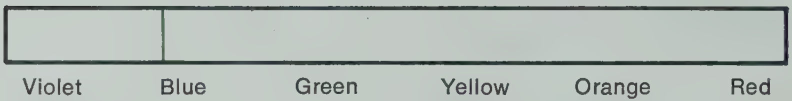
☐ **1-13.** Did you see any bright lines in the spectrum of the alcohol lamp? If so, what colors were they?

Same answer as for 1-12

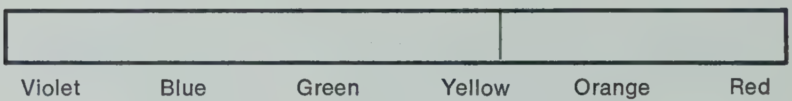
☐ **1-14.** In the space provided, show the position and color of any bright lines you saw in the spectrum. Do this for Activities 1-8 and 1-9 also.



Li



Sr



Na

☐ **1-15.** Look at your answers for question 1-14. Were your spectra drawings different for LiCl, SrCl, and NaCl?

Yes

☐ **1-16.** Match the spectra from Figure 1-2 with the chemicals you observed.

LiCl A

SrCl B

NaCl C

☐ **1-17.** Remember the "how" question 1-1? Can you answer it now? If so, do it.

Answers will vary, but should indicate the use of spectra to distinguish elements of the sun.

PROBLEM BREAK 1-1

☐ **1-18.** Show the position of any bright lines you identify.

(Lines depend on combination used.)

Violet Blue Green Yellow Orange Red

☐ **1-19.** Compare the sketch you made with the sketches you made in answer to question 1-14. What substance or substances do you predict are in the unknown solution?

Answers depend on combinations used by the teacher.

If desired, you can set up 3 different combinations of the 3 substances (Li & Sr, Li & Na, Sr & Na). Lines would then be a combination of the lines for 1-14.

CHECKUP 2-1

Chapter 2
Watt's Hot?

1. Work is
- **a.** force.
- **b.** distance.
- ✓ **c.** force × distance.
- **d.** speed × time.

2. A measure of energy is
- **a.** force.
- ✓ **b.** force × distance.
- **c.** speed × time.
- ✓ **d.** work.

3. Energy can
- **a.** exist only in the form of heat.
- ✓ **b.** exist in more than one form.
- ✓ **c.** be transferred from one system to another.
- ✓ **d.** cause changes in matter.

4. Energy is always
- ✓ **a.** conserved.
- **b.** destroyed.
- ✓ **c.** needed to overcome forces.
- **d.** a measure of the time needed to do work.

☐ **2-1** How much an object's temperature changes when exposed to sunlight depends on a number of things. Which of the following things do you think could affect this change?

- **A.** How big the object is
- **B.** How well it absorbs heat
- **C.** How quickly it conducts heat
- **D.** How long it is heated

All of them

☐ **2-2.** What do you predict will happen to the copper strip if it is placed in sunlight?

It will get hot.

☐ **2-3.** What is the purpose of the thermometer?

To measure change in temperature

☐ **2-4.** Was the thermometer reading in the shade different from that in the sun? (If so, how much?)

Yes (A change of 1° to 4° can be expected in 3 minutes.)

☐ **2-5.** What could you do to the copper to make it absorb more of the sun's energy?

Make it less shiny.

☐ **2-6.** At room temperature, what temperature does the sun-energy measurer show?

Answers will vary (about 25–27 °C).

☐ **2-7.** What temperature does the instrument show after being in direct sunlight for a few minutes?

Answers will vary (about 15°–20° above room temperature).

☐ **2-8.** By how many degrees did the temperature change?

Anwers will vary.

☐ **2-9.** Why do you think copper was a good choice of metal?

It is a good conductor of heat; it is easily shaped (malleable).

Table 2-1

Table 2-1. These are sample data.

Time (minutes)	Temperature (°C)	Total temperature change (°C)
0.0	25	0
0.5	28	3
1.0	30	5
1.5	32	7
2.0	33	8
2.5	34	9
3.0	34	9
3.5	34.5	9.5
4.0	35	10
4.5	35	10
5.0	35	10

☐ **2-10.** What is the highest temperature you recorded during the 5 minutes?

35 °C

Figure 2-1

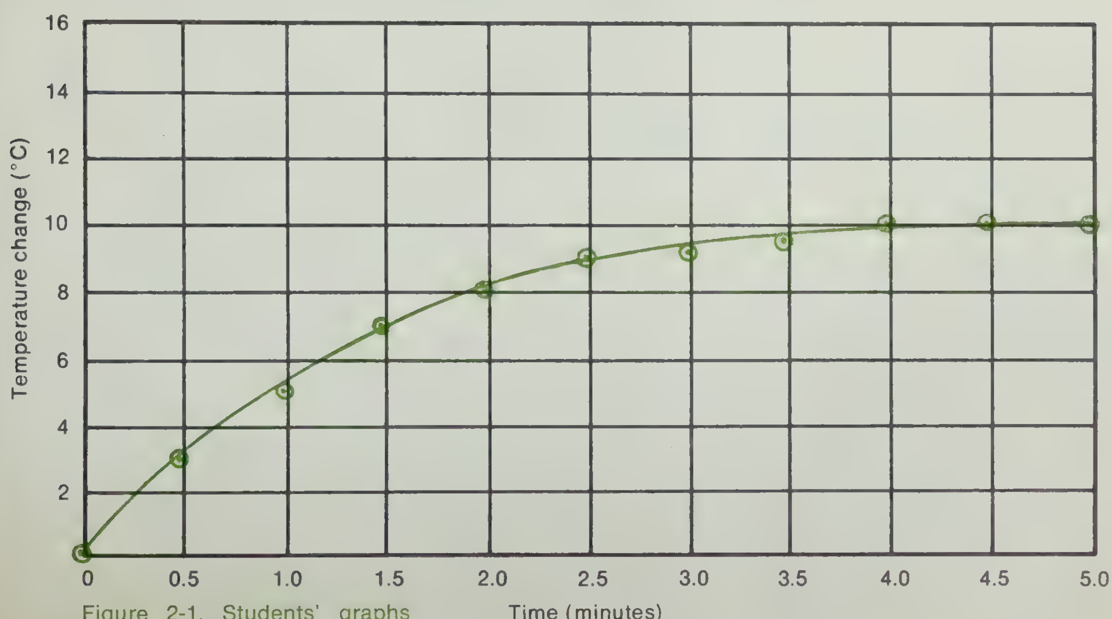


Figure 2-1. Students' graphs should approximate this shape.

☐ **2-11.** According to your graph, how much time passed before the temperature stopped rising?

Answers will vary (about 3–3½ minutes).

☐ **2-12.** Why, do you think, did the temperature stop increasing?

The amount of heat lost equaled the amount gained.

☐ **2-13.** List at least three variables that you think might have affected how much temperature change you observed.

Amount of time in the sun; area of the copper strip; distance from the light bulb; wattage of the light bulb; angle at which light strikes the strip

Table 2-2. These are sample data.

Table 2-2

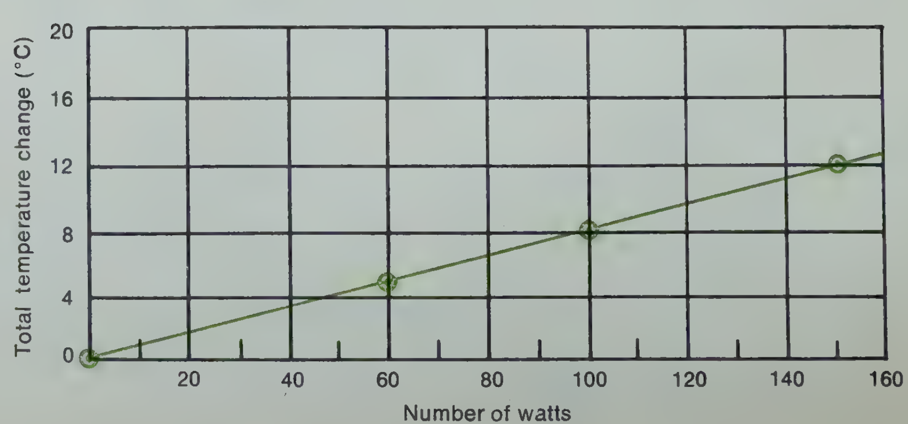
Bulb	Original temperature	Highest temperature	Temperature change
60W	25 °C	30 °C	5 °C
100W	25 °C	33 °C	8 °C
150W	25 °C	37 °C	12 °C

☐ **2-14.** Which of the following bulbs produces the most light energy: 150W, 60W, or 100W?

150W

Figure 2-2

Figure 2-2. Student's graphs should approximate this shape.



☐ **2-15.** What happened to the temperature change as the wattage (amount of energy) of the bulb increased?

It increased.

☐ **2-16.** Look at your graph in Figure 2-2. Predict the temperature change if you had used a 50-watt bulb.

Answers will vary (about 4 °C).

☐ **2-17.** Was your prediction in 2-16 correct?

Answer depends on prediction.

☐ **2-18.** How does the size (in watts) of a light bulb affect the temperature of the sun-energy measurer?

A higher wattage produces a greater temperature change on the sun-energy measurer.

Excursion 2-1
Energy at Work

☐ **1.** Give another example of the transfer of energy.

Answers will vary.

☐ **2.** Can you give an example of heat being changed to electricity?

Answers will vary.

☐ **3.** Can chemical energy be changed to electrical energy?

Yes

☐ **4.** Give an example or two of how energy causes a change in matter.

Answers will vary.

Chapter 3
Lights in the Distance

☐ **3-1.** What do you predict will be the effect of moving your light source farther away from the sun-energy measurer?

Predictions will vary.

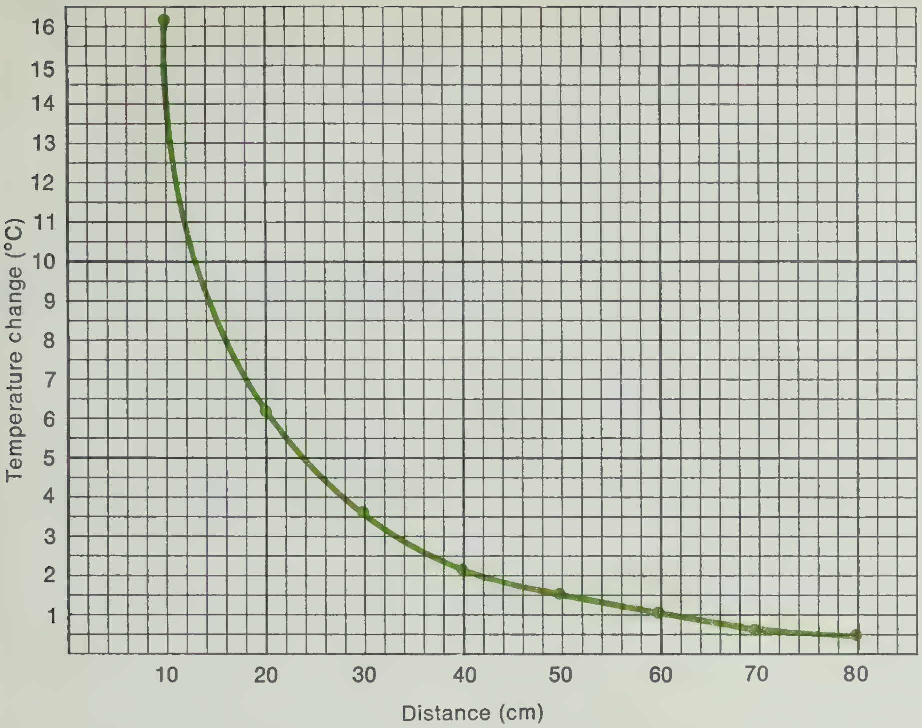
This Problem Break is the most important part of the chapter. The answers derived from it form the basis for the power measurement of the sun.

PROBLEM BREAK 3-1

Table 3-1

Distance (cm)	Temperature (°C)		Total temperature change (°C)
	Initial	Final	
10	25	41	16
20	25	31	6
30	25	28.5	3.5
40	25	27	2
50	25	26.5	1.5
60	25	26	1
70	25	25.5	0.5
80	25	25.5	0.5

Figure 3-1



☐ **3-2.** In your experiment, why should you keep the light source constant at 150 watts?

The wattage of the bulb is a variable that should be kept constant while investigating temperature change.

☐ **3-3.** How much temperature change did the sun-energy measurer show?

Answers will vary (6–20 °C).

☐ **3-4.** How far from a 150-watt bulb must the measurer be to show the same temperature it showed in direct sunlight?

Answers will vary (8–20 cm).

☐ **3-5.** Was your prediction in question 3-4 correct?

Answer depends on prediction in question 3-4.

Chapter 4
Far-Out Sun

☐ **4-1.** How does a range finder tell the difference in the distance to the two objects in Figure 4-1?

As the distance to the object increases, the angle decreases.

☐ **4-2.** Does the sighting bar still line up with the object after the range finder is moved? If not, what would you have to do to line it up? Try it!

No; the sighting bar has to be moved in toward the sighting line.

☐ **4-3.** Suppose you moved the range finder closer to the object along the sighting line. Predict what you would have to do to align the sighting bar.

Move it even closer to the sighting line.

☐ **4-4.** Was your prediction correct?

Answer depends on prediction in 4-3.

☐ **4-5.** Suppose the distance from the range finder to an object increases. How do you predict the angle between the sighting line and sighting bar will change?

The angle will decrease.

☐ **4-6.** Was your prediction in question 4-5 correct? What happens to the angle formed by the sighting bar and the parallel sighting line shown in Figure 4-2?

Answer depends on prediction; the angle will decrease.

☐ **4-7.** Suppose you lined up the sighting line and the sighting bar of the range finder in Figure 4-2 on an object a long way off (like a distant tree). Would you expect the angle between the sighting bar and the parallel sighting line to be large, or small?

Small

☐ **4-8.** Describe any problems you had in deciding which object was farther away.

Answers will vary.

☐ **4-9.** From the position of the sighting bar on your scale, what can you say about the distance to the sun?

It's too far to measure.

☐ **4-10.** Suppose you lengthened the base line. How would this affect the greatest distance you can measure with your range finder?

It would increase the distance the range finder can measure.

PROBLEM BREAK 4-1

Problem Break 4-1. Note the instructions for the student to check with you before proceeding with the experiment. Are all factors but the base line and the distance held constant? How will the measurements be made?

Teacher's initials

☐ **4-11.** In Figure 4-3, how would increasing the base line affect the size of the angle between the two sighting lines?

It would increase the angle.

☐ **4-12.** If you switched from a simple range finder to the system shown in Figure 4-4, what effect would this change have on angle A?

It would increase the angle.

Excursion 4-1

The Moon's Measurements

☐ **1.** How many minutes did it take the moon to pass across the wire?

About 2 minutes

☐ **2.** In question 1, you recorded the minutes it takes for the wire to sweep one moon diameter. How many minutes did this sweep take?

About 2 minutes

☐ **3.** How many minutes does it take the earth to make one complete rotation?

1440 minutes

☐ **4.** How many moon diameters would a telephone wire sweep across in one full day? (Hint: You know the time needed to sweep across one moon diameter. You also know how many minutes there are in one full day.)

About 720 moon diameters

☐ **5.** What is the diameter of the moon?

3330 km

Chapter 5
Measuring the Distance to the Sun

☐ **5-1.** How could the distance from Earth to Venus be used in measuring the distance to the sun?

Answers will vary. Hopefully the student will indicate using the Earth–Venus distance as a base line.

☐ **5-2.** Why can't the range finder you used in Chapter 4 measure large distances?

The base line is too short; or the sighting angle is too small.

☐ **5-3.** What problems would there be in using the scheme in Figure 5-2?

Answers will vary.

☐ **5-4.** Why is the sun placed at the center of the drawing?

Because the sun is the center of the solar system

☐ **5-5.** What does "in the same plane" mean?

Answers will vary. Hopefully, the student will indicate that Earth and Venus do not travel at a vertical angle to one another.

☐ **5-6.** Why are the orbits of Venus and Earth represented by circles in your drawing?

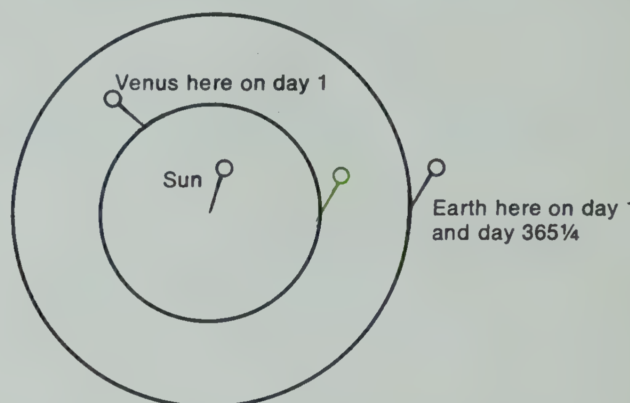
Because they move in a circular path

☐ **5-7.** Why is the circle for Venus's orbit smaller than the circle for Earth's orbit?

Venus is closer to the sun.

☐ **5-8.** Suppose the planet Earth made a complete orbit around the sun. During that time, would Venus have made more, or less, than one orbit around the sun? (Answer by drawing the approximate position of Venus in Figure 5-3.)

Figure 5-3



☐ **5-9.** Does Venus travel faster, or slower, than Earth as it moves around the sun?

Venus travels faster.

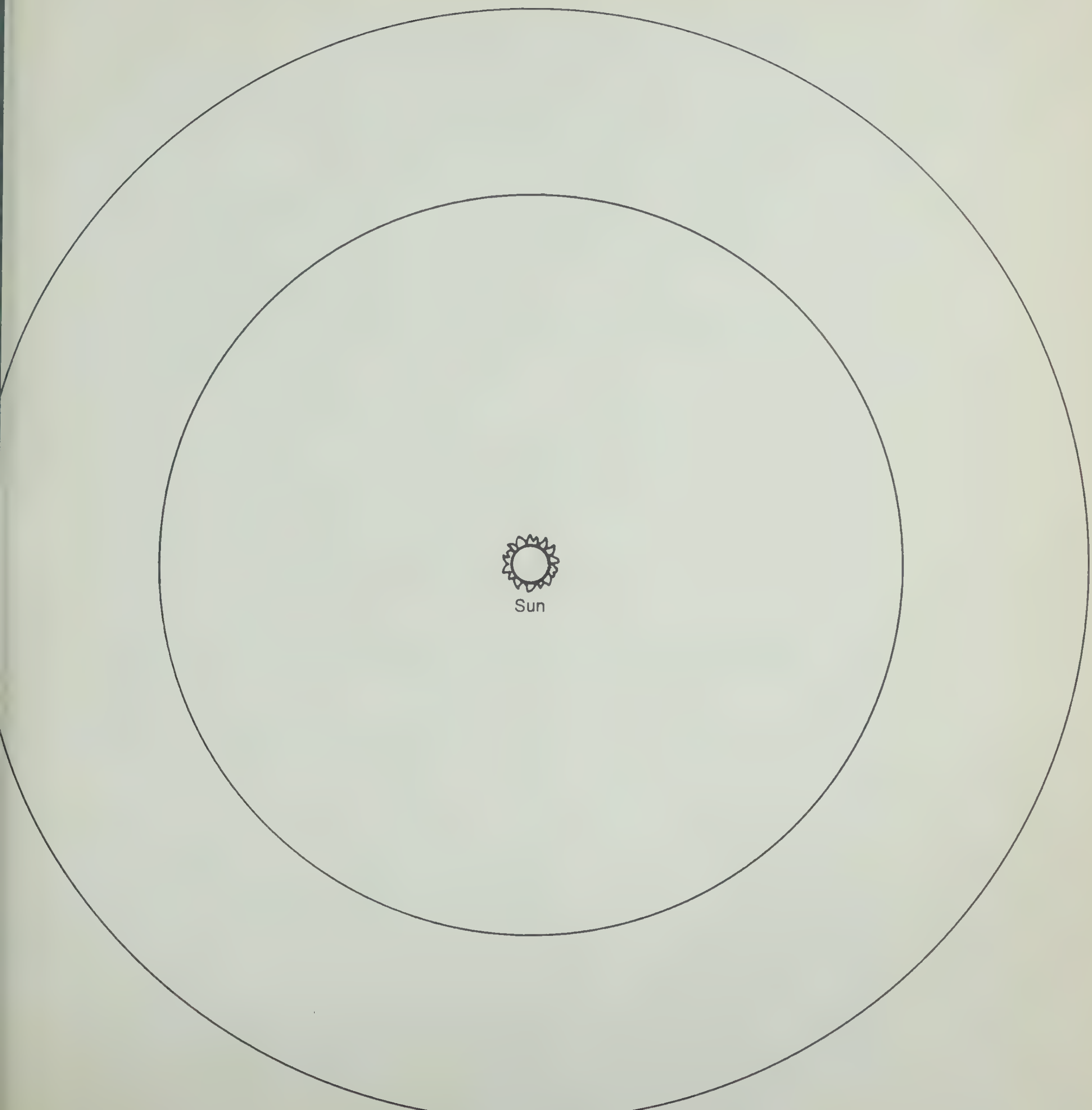
☐ **5-10.** In Figure 5-4, which drawing shows the pins not in a triangle?

Drawing D

☐ **5-11.** In Activity 5-4, what measurement could be made to describe the position of Venus with respect to the sun and Earth?

The angle formed by line EV (the line of sight from Earth to Venus) and line ES (the line of sight from Earth to the sun)

ACTIVITY 5-1



☐ **5-12.** As Venus and Earth move in orbit, what two things happen to the angle formed by EV and ES?

The angle increases and straightens out.

☐ **5-13.** When is the EV–ES angle greatest?

When the line of sight from Earth to Venus just touches but does not cut the orbit of Venus

☐ **5-14.** What number of degrees are there in the greatest possible EV–ES angle?

About 41° on the scale drawing

☐ **5-15.** When is the EV–ES angle smallest?

When Earth, Venus, and the sun are in line (0°)

☐ **5-16.** What is the largest average Sun–Earth–Venus angle astronomers have measured?

46°

ACTIVITY 5-6.

This 15-cm-diameter circle, and the lines and angles drawn on it, should be carefully and accurately done. The distances in Table 5-2 depend on this scale drawing.

CHECKUP 5-1

1. How high (in metres) was the crate from which the scale drawing was made?

4 m

2. How wide (in metres) was the actual crate?

3.5 m

☐ **5-17.** Measure on your scale drawing from Activity 5-8 the distance between Earth and Venus when they are closest together. This will be when Earth, Venus, and the sun are lined up. Also Earth and Venus are on the same side of the sun. See Figure 5-7.

About 21 mm

☐ **5-18.** What is the distance in mm between E and V on your scale drawing?

42 mm

☐ **5-19.** By your scale, how many km are represented by each mm?

2 000 000 km

Table 5-2

	On scale drawing (mm)	Actual (km)
Distance from Venus to the sun	54	108 million
Distance from Earth to the sun	75	150 million
Smallest distance between Earth and Venus	21	42 million

☐ **5-20.** Using your scale drawing, measure (in millimetres) the distance from Venus to the sun. Then measure the distance from Earth to the sun. Record your measurements in Table 5-2.

54 mm; 75 mm

☐ **5-21.** Using your scale of 1 mm = 2 000 000 km, calculate the distance in km from Venus to the sun and from Earth to the sun. Record the results of your calculations in Table 5-2.

108 000 000 km; 150 000 000 km

Excursion 5-1

What's Radar?

☐ **1.** How far will a radio pulse travel in 1 minute if it moves 300 000 km/sec?

18 000 000 km

☐ **2.** The pulse takes 2.33 minutes to travel from Venus to Earth. How far has the pulse traveled?

41 940 000 km, or 42 000 000 km

☐ **3.** How far is Venus from Earth?

42 000 000 km

Excursion 5-2
Scale Drawings

☐ **1.** What scale did the architect use?

1 cm = 10 m

☐ **2.** How many centimetres wide is the storage area as shown in the drawing?

4 cm

☐ **3.** When the warehouse is actually built, how wide will the storage area be?

40 m

☐ **4.** Use the information in Figure 2 to answer these questions: What is the actual distance?
A. from Boston to Chicago?
B. from Chicago to San Francisco?
C. from Chicago to New Orleans?

A. 1344 km

B. 2880 km

C. 1344 km

Excursion 5-3
Practice in Using Scale Drawings

Table 1

Table 1. These figures are rounded off.

	Scale drawing (mm)	Actual distance (km)
Venus to Sun (VS)	43	106 000 000
Earth to Sun (ES)	60	148 000 000
Earth to Venus (EV)	17	42 000 000

☐ **1.** From Table 1 you see that 17 mm on the drawing represent 42 000 000 actual km. How many actual km would be represented by 1 mm? Of course, $\frac{1}{17}$ as many km, or 1 mm on the drawing, represents $\frac{1}{17}$ × 42 000 000 actual km = how many km?

2 470 000 km

☐ **2.** How many actual km would be represented by 2 mm on the drawing?

4 940 000 km

☐ **3.** Now figure out the Venus-sun distance for Table 1. How many actual km are represented by 43 mm? Forty three mm in the drawing represent $\frac{43}{17}$ × 42 000 000 actual km = how many km?

106 210 000 km

☐ **4.** Using the same method, you can find the Earth-sun distance. The Earth-sun distance on your drawing is 60 mm. How many actual km are represented by 60 mm?

148 200 000

Chapter 6
How Big Is the Sun?

☐ **6-1.** What is the distance (in cm) from the pinhole to the square hole in the light-intensity board?

42 cm

☐ **6-2.** What is the distance (in cm) from the pinhole to the grid (the length of the cardboard tube)?

42 cm

☐ **6-3.** Now what is the distance (in cm) from the pinhole to the square hole in the light-intensity board?

84 cm

☐ **6-4.** How many times bigger is the distance across the square hole in the cardboard (1 cm) than the distance across the image (0.5 cm)?

Twice as big

☐ **6-5.** What is the distance in cm from the pinhole to the grid?

54 cm

☐ **6-6.** What is the distance across the sun in km? (If you make the calculation shown above, your answer will automatically come out in km because the centimetres cancel out.)

1 380 000 km

Excursion 6-1
Moon Gazing

☐ **1.** Suppose a telescope has an object lens with 30-cm focal length and an eyepiece lens with 5-cm focal length. What is the power of the telescope?

6 power

☐ **2.** Why are giant telescopes at observatories placed on massive concrete foundations?

To prevent unwanted motion in the telescope

☐ **3.** What is the focal length, in cm, of the object lens?

45 cm

☐ **4.** What is the focal length of the eyepiece lens, in cm? (It should be much shorter than that of the object lens.)

4 cm

☐ **5.** Using the equation given earlier, calculate the power of your telescope.

11.25 power

☐ **6.** Describe anything different about the image that you observe. (Different means from what you would see with the naked eye.)

The image is inverted.

☐ **7.** Why would what you observed not be bothersome to astronomers?

Answers will vary, but should indicate that the image need not

be right side up for observation purposes.

☐ **8.** How far apart should the lenses be in your telescope to give it the maximum magnification? (See your answers to questions 3 and 4.)

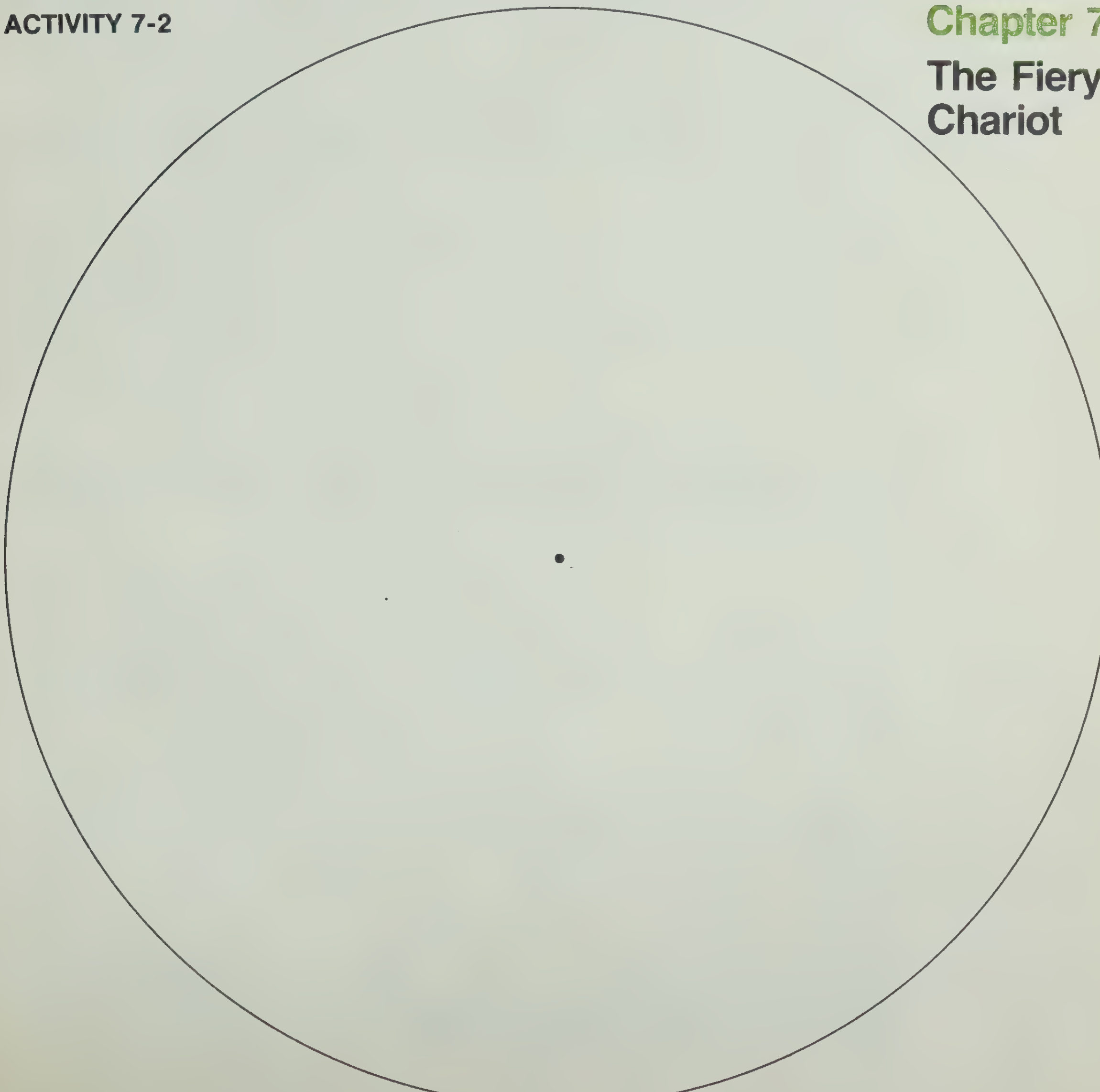
About 49 cm

☐ **9.** Give the descriptive numbers for the power and light-gathering ability of your telescope.

11 × 34

Chapter 7
The Fiery Chariot

ACTIVITY 7-2



☐ **7-1.** Suppose you were the observer standing on the earth in Figure 7-1. Would the sun appear to be overhead, or on the horizon?

On the horizon

☐ **7-2.** In Activity 7-4, would the sun appear to be overhead to the observer?

Yes

☐ **7-3.** How many degrees did you have to turn the earth to get the sun overhead?

90°

☐ **7-4.** How many degrees have you turned the earth from where it started (in Figure 7-1)?

180°

☐ **7-5.** To the observer represented by the map pin, would the sun seem to have traveled across the sky from one horizon to the other?

Yes

☐ **7-6.** Suppose you kept turning the earth disk until the map pin got back to where it started. Through a total of how many degrees would the earth disk have turned?

360°

☐ **7-7.** With the earth and the sun in the position shown in Activity 7-7, would the observer see the sun overhead, or on the horizon?

On the horizon

☐ **7-8.** How many degrees did you move the sun to make it appear overhead to the observer?

90°

☐ **7-9.** How many degrees did you have to move the sun from its position in Activity 7-7 to make it appear to the observer that it moved from one horizon to the other?

180°

☐ **7-10.** In both cases, did the sun appear to the observer to move around the earth?

Yes

☐ **7-11.** In both cases, did the sun appear to the observer to rise from one horizon and set behind the other?

Yes

☐ **7-12.** At what time did you make your first mark?

Answers will vary.

☐ **7-13.** At what time did you make a second mark?

30 minutes after the time in 7-12

☐ **7-14.** How many degrees are in the angle formed by the two shadow lines?

10° to 20°

7-14. Geographic location and time of day will affect the answers. Students' answers for this question and also for 7-18 to 7-21 should fall in the ranges shown.

☐ **7-15.** How many degrees did the sun appear to move in 30 minutes?

10° to 20°

☐ **7-16.** How many km does each mm represent?

1 mm = 1 000 000 km

☐ **7-17.** The arc between 1 and 2 shows how far the sun appears to travel in what perriod of time?

30 minutes

☐ **7-18.** What is the distance in mm from point 1 to point 2 on your circle?

8 to 16 mm

☐ **7-19.** Using the scale you determined in question 7-16, what is the distance in kilometres that the sun traveled in 30 minutes?

8 000 000 to 16 000 000 km

☐ **7-20.** If its speed is steady, how far would it travel in 1 hour?

16 000 000 to 32 000 000 km

☐ **7-21.** What would its speed in kilometres per hour have to be?

16 000 000 to 32 000 000 km/h

☐ **7-22.** Can you think of a way to calculate how fast the earth is turning? (Hint: The distance around the earth is 40 000 km.)

Answers will vary. Hopefully, the student will realize that the earth rotates 40 000 km in 1 day (24 h), or 1600 km/h.

PROBLEM BREAK 7-1

Excursion 7-1
The Night That People Lost 10 Days

☐ **1.** How many days shorter than our year was the Sumerian year?

5 days

☐ **2.** About how often should the Sumerians have added a 30-day month to get a year as long as ours?

About every 6 years

☐ **3.** You may have heard the famous quote from Shakespeare's *Julius Caesar:* "Beware the ides of March." What is meant by the ides of March?

That part of March in which there was a full moon

☐ **4.** See if you can explain why Easter would have to occur within these dates in order to meet the council requirements.

Answers will vary. (If March 21 came on Saturday and there was a full moon that day, then the first Sunday after the first full moon on or after March 21 would be March 22. If March 21 came on Sunday and there was a full moon the day before, March 20, then the next full moon would be a lunar month later [$29^1/_2$ days] on Sunday, April 18, and the first Sunday after that is April 25.)

☐ **5.** Can you explain why it is October 15 in Rome and only October 5 in London following Pope Gregory's decree?

The British did not accept Pope Gregory's decree.

Excursion 7-2
Matching Wits with Galileo

☐ **1.** Which theory do you support?

Theory of Copernicus

☐ **2.** What are your reasons for supporting the theory?

Answers will vary, but should indicate that with the Ptolemaic theory it would never be possible to see more than a crescent of Venus, while with the Copernican theory all phases from crescent to full would be possible, and this, in fact, is what can be observed.

Chapter 8
On Your Own

☐ **8-1.** How do astronomers know what the sun is made of?

They know what the sun is made of by studying its light with spectroscopes.

☐ **8-2.** How can you find out how much energy the sun gives off each minute?

Compare its effect on the sun-energy measurer with a known light source at a known distance.

☐ **8-3.** How can the distance to the sun be determined?

By using scale drawings and the EV-ES angle

☐ **8-4.** How can the size of the sun be determined?

By projecting its image on a screen and using a simple mathematical relationship

☐ **8-5.** How can the motion of the sun be described?

The sun apparently moves around the earth; however, it is more likely that the earth moves around the sun.

☐ **8-6.** Would the heat from a 150-watt bulb warm up your sun-energy measurer if the bulb were 149 million km away?

No

Table 8-1

If the original distance from source to object is multiplied by	Then the original power of the source must be multiplied by
2	4
3	9
4	16
10	100
50	2500
100	10 000
1000	1 000 000

☐ **8-7.** The numbers in Table 8-1 have a very interesting relationship. What do you think that relationship is?

The number in column 2 is the square of the number in column 1

☐ **8-8.** Suppose the original distance is multiplied by 10 000. What do you predict the power multiplier to be?

100 000 000

☐ **8-9.** What is the distance in cm you found for the position of the 150-watt bulb?

8–20 cm

☐ **8-10.** How many cm are there in 149 000 000 km?

14 900 000 000 000 cm

☐ **8-11.** Now divide your answer to question 8-10 by R. (The result will be the number of times R must be multiplied to give you the distance to the sun.) Record this number in the last row of Table 8-1 as a distance multiplier.

1 860 000 000 to 745 000 000

☐ **8-12.** What is the power multiplier that goes with the distance multiplier you recorded in Table 8-1? Record your answer in Table 8-1.

3 460 000 000 000 000 000 to 550 000 000 000 000 000

8-13. Many factors might influence students' estimates. Values ranging from 10^{24} to 10^{26} watts may be possible on sunny days at noon. The exact value for the sun is 3.7×10^{26} watts.

☐ **8-13.** What is the sun's energy measured in watts? (150 watts × power multiplier)

520 000 000 000 000 000 000 to 82 500 000 000 000 000 000 watts

☐ **8-14.** According to the spectra, how do the chemical compositions of the stars compare?

Star A contains the elements helium and hydrogen, and Star B contains hydrogen and calcium.

☐ **8-15.** How much farther away is Star A than Star B?

Twice as far away

☐ **8-16.** How does the energy of Star A compare with that of Star B?

The energy received from Star B is twice as much as that from Star A.

How Am I Doing?

You probably wonder what exactly you are expected to learn in this science course. You would like to know how well you are doing. This section of the book will help you find out. It contains answers to the Self-Evaluations for each chapter. If you can answer all the questions, you're doing *very* well.

Self-Evaluations are for your benefit. Your teacher will not use the results to give you a grade. But you may want to grade yourself.

Some questions can be answered in more than one way. Your answers to these questions may not quite agree with those in the Answer Key. If you miss a question, review the material on which it was based before going on to the next chapter. Page references are frequently included in the Answer Key to help you review.

On page 61 of this booklet, there is a grid that you can use to keep a record of your progress.

TO THE TEACHER The following sets of questions have been designed for self-evaluation by your students. The intent of the self-evaluation questions is to inform the student of his or her progress. The answers are provided for the students to give them positive reinforcement. For this reason it is important that each student be allowed to answer these questions without feeling the pressures normally associated with testing. We ask that you do not grade the student on any of the chapter self-evaluation questions or in any way make the student feel that this is a comparative device.

The student should answer the questions for each chapter as soon as the student finishes the chapter. After answering the questions, the student should check his or her answers immediately by referring to the appropriate set of answers in the back of his Record Book.

There are some questions that require planning or assistance from the classroom teacher or aide. Instructions for these are listed in color on the pages that follow. You should check this list carefully, noting any item that may require your presence or preparation. Only items which require some planning or assistance are listed.

You should check occasionally to see if your students are completing the progress chart on page 61.

SELF-EVALUATION 1

1-1. Describes what a spectroscope does to reflected sunlight.

☐ **1-1.** Describe what is produced when sunlight is reflected from a piece of white paper and passed through a spectroscope.

____

____

____

1-2. Describes the difference between continuous and bright-line spectra.

☐ **1-2.** Describe the difference between the fluorescent-tube spectrum and the sunlight spectrum.

____

____

____

-3. Recalls the characteristics of the spectrum of sodium when burned and identifies it as bright-line.

☐ **1-3.** A nichrome wire is used to put a solution of sodium chloride into an alcohol flame. The light given off is viewed through a spectroscope.

a. What type of spectrum can be seen?

____

b. In Figure 1-3, sketch the spectrum of sodium chloride.

Figure 1-3

Violet Blue Green Yellow Orange Red

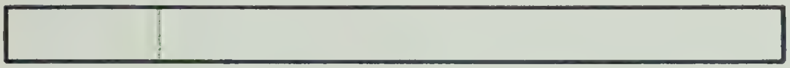
☐ **1-4.** Which spectrum below is best represented by Figure 1-4? (Check one.)

1-4. Distinguishes between a continuous and a bright-line spectrum.

______Bright-line spectrum

______Continuous spectrum

Figure 1-4



☐ **1-5.** Why should you never look directly at the sun through a spectroscope?

1.5 Explains the safe use of a spectroscope.

____

____

☐ **1-6.** After each source listed in Table 1-6, check the type of spectrum produced.

1-6. Matches different light sources with their spectral types.

Table 1-6

Source	Continuous	Bright-line
75-watt bulb		
Fluorescent tube		
Sodium vapor lamp		
Reflected sunlight		

☐ **1-7.** Describe the difference between the dark-line spectrum and the bright-line spectrum for the same element.

1-7. Describes the difference between bright-line and dark-line spectra

____

____

____

☐ **1-8.** Obtain the container labeled "Question 1-8" from your teacher. Use a flame test to determine which of the elements (Na, Li, Sr) the solution contains.

1-8. Applies method for identifying chemicals by using a spectroscope.

____

1-8. You should prepare (and label "Question 1-8") a mixture of two of the three substances used in the chapter. Note that you can use the same ones that were prepared for Problem Break 1-1 if you desire.

1-9. Applies the concept that spectral data can be used to identify chemical elements of light sources.

☐ **1-9.** How can spectroscopes be used to help astronomers find out what stars like the sun are made of?

____

____

____

☐ **1-10.** The main purpose of this module is to show what astronomers have learned about the sun and solar system. (True or False)

____

SELF-EVALUATION 2

If you did the excursion for this chapter, write its number here.

____

2-1. Indicates that light and heat are forms of energy and that light can be converted into heat.

2-2. Explains the blackening of the vanes of the sun-energy measurer.

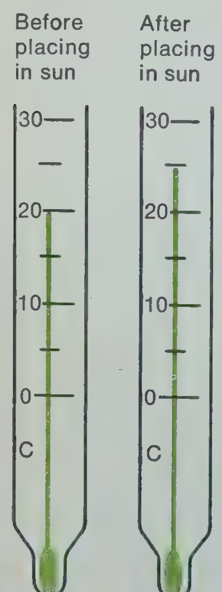
☐ **2-1.** Light and heat are forms of ____________. Light (can, cannot) be converted into heat.

☐ **2-2.** Explain why the blades of the sun-energy measurer were blackened.

____

____

Figure 2-3



☐ **2-3.** How many degrees Celsius change in temperature occurred after the thermometer was placed in the sun (Figure 2-3)?

____

2-3. Accurately reads the change in temperature, using a Celsius thermometer scale.

☐ **2-4.** List three factors that affect the temperature change of a sun-energy measurer.

a. ______________________________

b. ______________________________

c. ______________________________

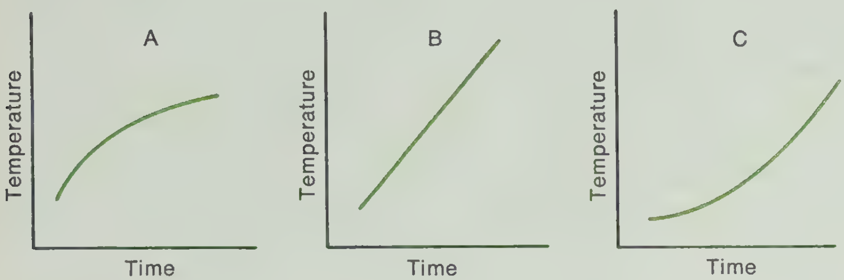
2-4. Lists the variables that affect an object's temperature change.

☐ **2-5.** Using your sun-energy measurer, measure the temperature change caused by the light bulb that your teacher has prepared. Check your answer with your teacher. What was the maximum temperature change?

2-5. Use a 100-watt bulb at a distance of about 15 cm from the sun-energy measurer. You will probably want to try it out ahead of time and adjust the distance so that there is a 15°C change.

2-5. Uses the sun-energy measurer to measure temperature change due to light source.

Figure 2-6



☐ **2-6.** Which of the graphs in Figure 2-6 best shows how the temperature of the sun-energy measurer changes after being placed in direct sunlight?

2-6. Selects graph showing that a sunlit object's temperature reaches and maintains a maximum in a finite time span.

☐ **2-7.** The effect of different wattages of light bulbs on the temperature change of your sun-energy measurer can be measured as shown in Figure 2-7. The distance between the light sources and the energy measurer should be kept the same at all times. The amount of time that each bulb shines on the measurer should also be kept the same. Why is it important to keep the time and distance variables constant?

2-7. Explains why only one variable is changed at a time.

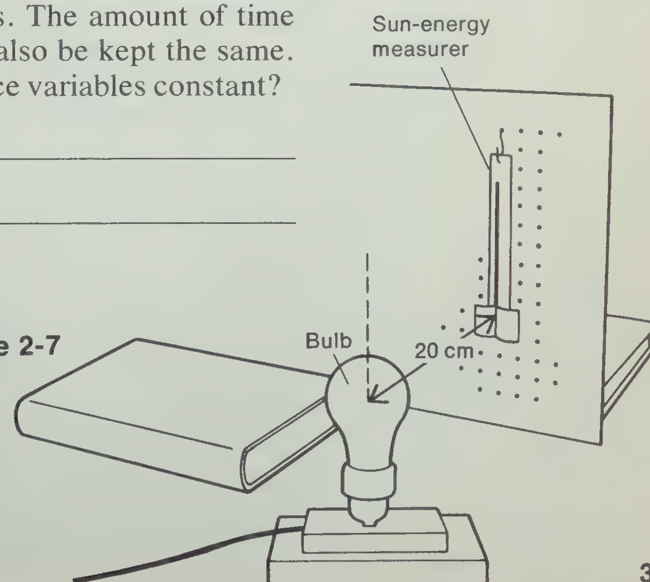


Figure 2-7

2-8. Identifies relative energy output of bulbs of different wattage.

☐ **2-8.** List the following wattages in order from lowest to highest in terms of light-energy production: 40 W, 15 W, 100 W, 60 W, 150 W.

2-9. Applies the concept that temperature change is directly related to energy output of light source.

☐ **2-9.** Three different-watt bulbs were placed, one at a time, the same distance from a sun-energy measurer. Each bulb was allowed to burn for the same amount of time. Which bulb would produce the greatest temperature change?

SELF-EVALUATION 3

☐ **3-1.** The data in Table 3-1 were obtained by using a sun-energy measurer, a 100-watt bulb, and various distances.

Table 3-1

Distance (cm)	Initial temperature °C	Final temperature °C	Temperature change °C
10	25.4	38.4	
15	25.0	32.0	
20	25.2	29.2	
25	25.0	27.5	
30	24.9	26.5	
35	25.1	26.1	

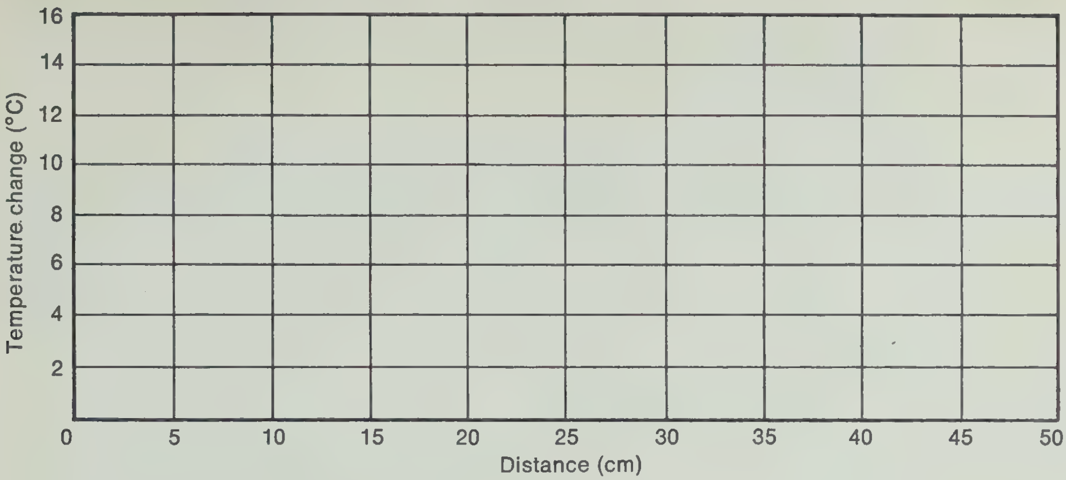
3-1a. Calculates temperature change.

3-1b. Selects ordered pairs and constructs a graph.

a. Complete the above table by calculating the temperature change.

b. On the grid in Figure 3-1, plot the temperature change against the distance.

Figure 3-1



c. Predict the temperature change at 40 cm.

3-1c. Extrapolates from graphed data.

☐ **3-2.** Suppose a 150-watt bulb produced an 8 °C change in the temperature of the sun-energy measurer at 20 cm. What temperature change would you expect the bulb to produce if moved to 40 cm from the sun-energy measurer?

3-2. Applies relationship of inverse effect of distance from energy source on temperature change of sun-energy measurer.

If you did the excursion for this chapter, write its number here.

SELF-EVALUATION 4

4-1. Identifies parts and characteristics of a range finder.

☐ **4-1.** Use Figure 4-1 to answer this question. The diagram illustrates a range finder sighted at an object.

a. Label the base line, the sighting line, and the sighting bar on the diagram.

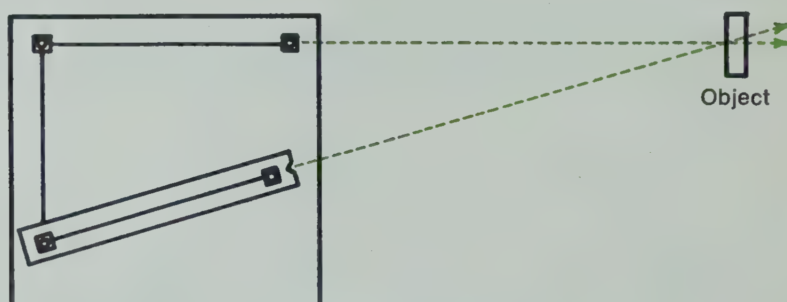
b. Suppose the range finder was moved farther from the object, but the sighting line was kept lined up with the object. Check the phrase below that best describes what you would need to do to align the sighting bar.

_______ Move the sighting bar toward the base line.

_______ Move the sighting bar away from the base line.

_______ Leave the sighting bar in the same position.

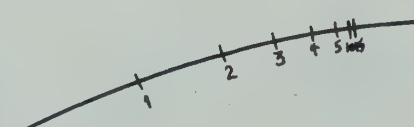
Figure 4-1



4-2. Explains scale markings on a range finder and how they can be varied.

☐ **4-2.** Figure 4-2 shows a range-finder scale similar to the one you made for distances of 1 m to 15 m.

Figure 4-2



a. Describe how the distance between the scale markings changes as the distance to the object increases.

____

____

b. Describe how you could change your range finder so that there would be more space between the scale markings.

____

____

☐ **4-3.** As the distance to the object being sighted increases, what happens to the sighting angle?

4-3. States the relationship of distance and sighting angle.

___

___

☐ **4-4.** What are some of the factors that limit the distance you can measure with a range finder?

4-4. Identifies factors that limit the use of a range finder.

___

___

☐ **4-5.** Your teacher has labeled an object "4-5A" somewhere in the room. He or she has also marked with an "X" a place for you to stand. Using your range finder, stand at the place marked "X" and sight the object labeled "4-5A." What is the distance to the object?

4-5. Some vertical object, such as the edge of a door, a chalkboard, or a wall corner, should be designated as "4-5A." At a horizontal distance of 3.75 metres from the designated object, mark an "X" on the floor.

4-5. Demonstrates skill in measuring distance by using a range finder.

___

___

☐ **4-6.** An astronomer made sightings at object Z from two observatories, located at X and Y as shown in the diagram below. Which line on the diagram represents the base line? (Check one.)

4-6. Identifies the base line for astronomical sightings.

_____ **a.** Line XZ

_____ **b.** Line XY

_____ **c.** Line YZ

_____ **d.** None of the above

☐ **4-7.** Why can't the range finder be used to measure the distance to the sun?

4-7. Explains why the range finder cannot be used to measure the distance to the sun.

___

___

___

SELF-EVALUATION 5

If you did any excursions for this chapter, write their numbers here.

____

5-1. Identifies basic facts about the solar system.

☐ **5-1.** Which of the following is an incorrect fact about the solar system?

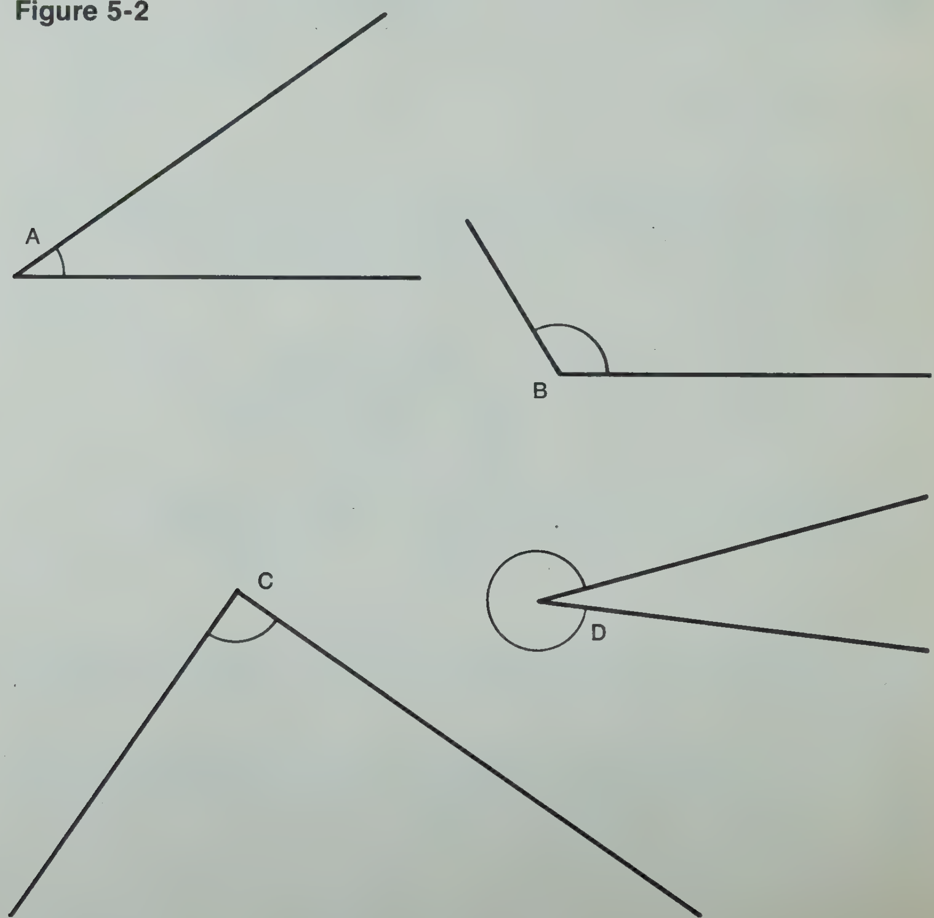
a. The sun is the center of the solar system.
b. Venus and Earth are planets that move in the same plane.
c. Earth is closer to the sun than Venus is.
d. Venus and Earth move in roughly circular orbits around the sun.

5-2. Uses a protractor to measure angles.

☐ **5-2.** Using your protractor, measure the four angles shown in Figure 5-2. The curved line indicates the angle that you are to measure.

Angle A =___ Angle B =___ Angle C =___ Angle D =___

Figure 5-2



☐ **5-3.** Use the scale drawing in Figure 5-3 to answer both parts of this question. (Measure the distance "as the crow flies," not the distance by road.)

5-3. Interprets scale drawings.

a. How far in centimetres is Union Park from Christmas on the drawing?

---

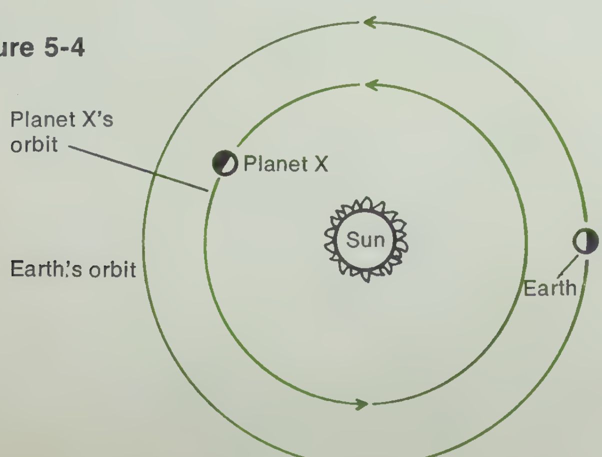
b. What is the actual distance in km between Union Park and Christmas?

Figure 5-3

☐ **5-4.** Use Figure 5-4 for this question. What is the greatest possible EX–ES angle for Planet X on this diagram?

5-4. Identifies and measures the greatest earth-planet, earth-sun angle from a drawing.

Figure 5-4



5-5. Prepares and uses a scale model of planet orbits to determine scale and actual distances between planets and distance from the earth to the sun.

☐ **5-5.** Use Figure 5-5 to answer all parts of this question.

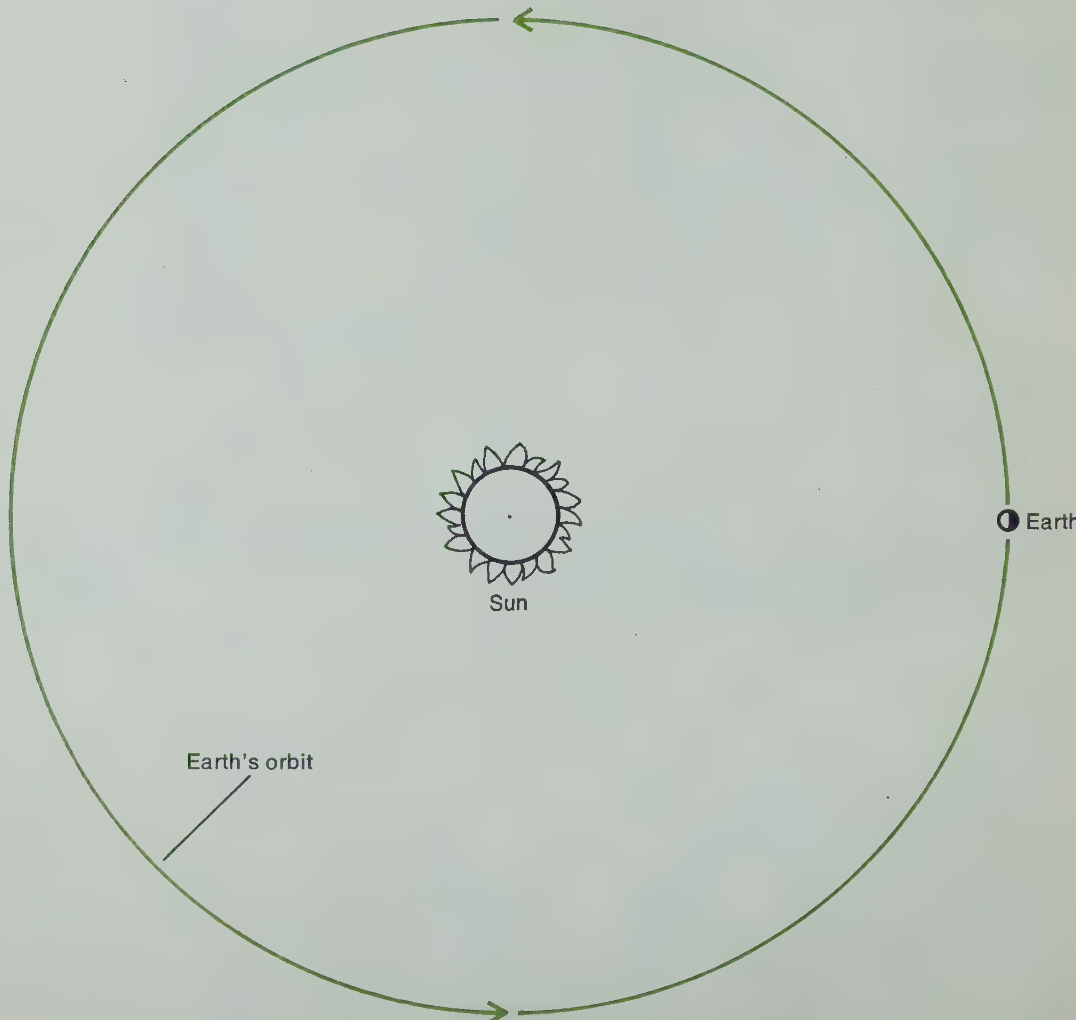
a. Draw in an earth–sun line on the diagram.

b. When, as seen from the earth, the Planet Z is at its greatest angle from the sun, the angle is 22°. Using your protractor, draw in the earth-Planet Z line when the EZ–ES angle is greatest (22°).

c. Using your compass, draw the orbit circle for Planet Z.

d. Measure the distance between the earth and the sun. Record this distance in mm on line 2 of Table 5-5.

Figure 5-5



e. On your scale, 1 mm equals how many km?

____

f. What is the distance in km from Planet Z to the sun?

---

g. What is the smallest distance between the earth and Planet Z?

---

h. Complete Table 5-5.

Table 5-5

		Scale drawing (mm)	Actual distance (km)
1	Distance from Planet Z to sun		
2	Distance from earth to sun		149 000 000
3	Smallest distance between earth and Planet Z		

If you did the excursion for this chapter, write its number here.

SELF-EVALUATION 6

☐ **6-1.** Describe the relationship between the size of the image formed and its distance from the pinhole and the size of the object and its distance from the pinhole.

6-1. Describes relationship of object and image size and distance to pinhole.

6-2. Set up the 150-watt light source with the 1-cm square hole lined up with the brightest part of the bulb. Make a mark for Point A so that the pinhole is 21 cm from the square hole; for Point B, make a mark at 31.5 cm; for Point C, a mark at 42 cm. It will help to have the apparatus in a darker part of the room if possible.

6-2. Demonstrates safe and accurate use of sighting scope.

☐ **6-2.** Your teacher has prepared an area where you will measure the size of a light source from three different distances. Take a pinhole-screen sighting scope to this area. Measure the size of the light source from Point A, Point B, and Point C. Keep the tube at its shortest length. The size of the image produced by the source when at

Point A = ____________ cm across.

Point B = ____________ cm across.

Point C = ____________ cm across.

6-3. Applies relationship of object and image size and distance to pinhole to calculate diameter of the moon.

☐ **6-3.** Using a pinhole-screen instrument, a student made some measurements to determine the diameter of the moon. Using the student's data (shown below), calculate the diameter of the moon.

Distance from moon to pinhole = 385 000 km
Distance from pinhole to screen = 57 cm
Size of moon image on screen = 0.5 cm

Actual diameter of moon = ____________ km.

6-4. Applies relationship of image, object size, and distance to pinhole in determining distance to the object.

☐ **6-4.** A light source that is 6 cm in diameter forms a sharp image 0.5 cm in diameter on the screen of your tube. The tube is adjusted so that the distance between the screen and pinhole is 20 cm. You do not know the distance from the light source to the pinhole of your tube.

a. In the space below, sketch a diagram that illustrates this problem.

b. How far away is the object from the pinhole?

____

If you did any excursions for this chapter, write their numbers here.

SELF-EVALUATION 7

☐ **7-1.** Answer the following questions based on the earth–sun model that you worked with in this chapter.

a. Through how many degrees does the earth turn from sunrise to sunset?

7-1a. Describes the earth's rotation in terms of degrees.

b. How many hours pass between the time the sun is overhead and the time it sets?

7-1b. Identifies length of time from noon to sunset.

☐ **7-2.** The time difference between New York and San Francisco is three hours. (When it is 12:00 noon in New York, it is 9:00 A.M. in San Francisco.) How many degrees on the surface of the earth does this represent?

7-2. Applies the concept that each hour represents 360/24 degrees of rotation.

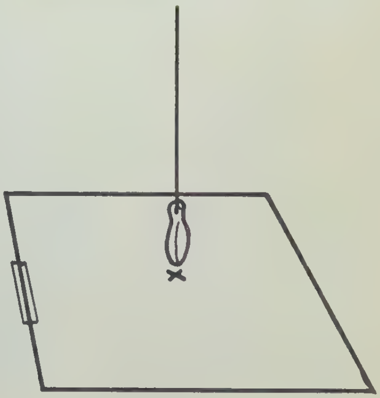
☐ **7-3.** How many time zones would you cross if you made a trip around the world?

7-3. Applies the concept that there is one time zone for every hour in a 24-hour day.

☐ **7-4.** Clint says that it is easy to see that the earth travels around the sun. He says all you need do is observe how the sun rises and sets each day. Do you agree with Clint?

7-4. Recalls that observations of the sun's motion can result in conclusions of both a sun-centered system and an earth-centered system.

☐ **7-5.** A student takes paper, sinker, and string outside on a bright sunny day to measure the movement of the sun. The string does not cast a shadow. What is the problem?



7-5. Indicates cause of a shadow's appearance and position, due to position of light source and object casting shadow.

7-6. Explains why it is more logical to think the solar system is sun-centered.

☐ **7-6.** Why is it more logical to think that the earth moves around the sun, even though you have not been able to prove it?

SELF-EVALUTION 8

If you did the excursion for this chapter, write its number here.

8-1. Applies concept of how energy received from light source diminishes with distance.

☐ **8-1.** When you double the distance from a light bulb, what must you do to the wattage of the bulb to keep the sun-energy measurer reading the same?

8-2. Applies concept of inverse square relationship.

☐ **8-2.** Complete Table 8-2.

Table 8-2

Distances and wattages required to keep the same reading on a sun-energy measurer

Measured distance	Wattage
80 cm	3 200 watts
160 cm	
	51 200 watts
640 cm	
2 560 cm	

☐ **8-3.** What does *power* mean as it applies to energy production?

8-3. Defines *power*.

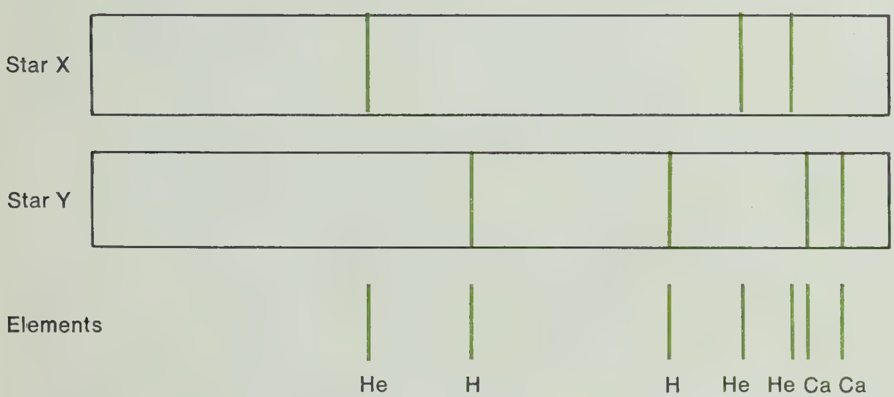
☐ **8-4.** Bulb X is placed 100 cm from the sun-energy measurer. Its effect is the same as a 20-watt bulb at 10 cm from the measurer. What is the power multiplier number you would use to get the wattage of bulb X?

8-4. Applies the concept that the power multiplier is the square of the distance multiplier.

☐ **8-5.** Light from two different stars, X and Y, is passed through a spectroscope. Their spectra and the spectral line positions of some elements are given in Figure 8-5. Use the spectra and the data in Table 8-5 to compare the composition and power (wattage) of the two stars.

8-5. Compares characteristics of stars, given spectral and energy data.

Figure 8-5



He = Helium
H = Hydrogen
Ca = Calcium

Table 8-5

Star	Distance from the earth	Temperature rise in sun-energy measurer
X	30 light-years away	13.6 °C
Y	15 light-years away	6.8 °C

8-6. Designs an experiment applying concept of energy measurement.

☐ **8-6.** Design an experiment to determine if a blue-colored 50-watt light bulb produces the same temperature change as an uncolored 50-watt light bulb when placed 10, 20, and 40 cm away from your sun-energy measurer. Use the space below for your answer.

Answer Key

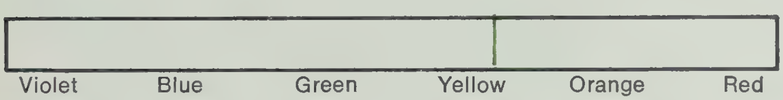
SELF-EVALUATION 1

1-1. A continuous spectrum. A continuous spectrum is like a rainbow of red, orange, yellow, green, blue, and violet. Try Activity 1-1 again if you had difficulty with this question.

1-2. The spectrum of a fluorescent tube forms a continuous spectrum like that of sunlight, but you can also see several bright lines on it. Try looking at the fluorescent-tube spectrum again if you have forgotten what it looks like.

1-3. a. Bright-line spectrum. The yellow lines (there are two of them if you look carefully) are caused by the sodium. The chlorine in the sodium chloride does not produce a spectrum at this temperature.

b.



1-4. Bright-line spectrum

1-5. Looking directly into the sun can produce permanent damage to the eyes. You should never look directly at the sun.

1-6. Your completed chart should look like the one below. Remember that a fluorescent tube produces both a bright-line and a continuous spectrum.

Source	Continuous	Bright-line
75-watt bulb	✓	
Fluorescent tube	✓	✓
Sodium vapor lamp		✓
Reflected sunlight	✓	

1-7. In the bright-line spectrum of an element, you do not see a continuous spectrum. You see only bright, colored lines in specific positions. The continuous spectrum is visible in the dark-line spectrum of the same element. But there are dark lines in the same positions that the bright lines occupy in the bright-line spectrum. (See pages 5 and 11.)

1-8. Check your answer with your teacher. If you had difficulty in identifying the element(s) present, you may want to do Activities 1-4 to 1-9 again.

1-9. Spectroscopes produce spectra. These spectra are like fingerprints of the elements that produced the light. Thus elements in light sources can be identified using spectroscopes.

1-10. False. This module shows *how* astronomers get answers to their questions about the sun and solar system. (See the first page of Chapter 1.)

SELF-EVALUATION 2

2-1. Light and heat are forms of energy. Light can be converted into heat. For more on energy, see **Excursion 2-1**.

2-2. The blades were blackened so that they would absorb light energy and convert it into heat energy more efficiently. You may have noticed this effect in the summer when walking barefoot—it's not too bad on light-colored concrete but look out for the black asphalt!

2-3. Change in temperature = 5 °C. See **Resource 7**, "Scale Reading," if you had trouble with this question.

2-4. You could have listed quite a number of factors, including whether or not the copper fin had been blackened, but there are three very important factors:

a. The intensity of the light source—the brighter the bulb, the greater will be the temperature change.

b. The distance between the sun-energy measurer and the light source—the smaller the separation, the greater will be the temperature change.

c. The length of time that the sun-energy measurer has been exposed to the light source. This is only noticeable for the first few minutes. After that the temperature changes very little or not at all. When this *equilibrium* temperature is reached, the copper strip is losing heat energy as fast as it is absorbing energy from the light.

2-5. Your answer should be fairly close to 15 °C. If you were not close to this answer, you may not have allowed enough time for your sun-energy measurer to heat up. If this doesn't solve your problem, check with your teacher to see whether your sun-energy measurer is working properly.

2-6. Graph A. The temperature rises and then levels off as the sun-energy measurer releases heat at the same rate it absorbs heat.

2-7. Only one variable is changed at a time so that the effect of that variable is not confused with the effects of the other variables. See **Resource 6**, "Investigating Variables," if you had trouble with this question.

2-8. 15 W, 40 W, 60 W, 100 W, 150 W. The higher the wattage of a bulb, the more energy it can release in the form of light.

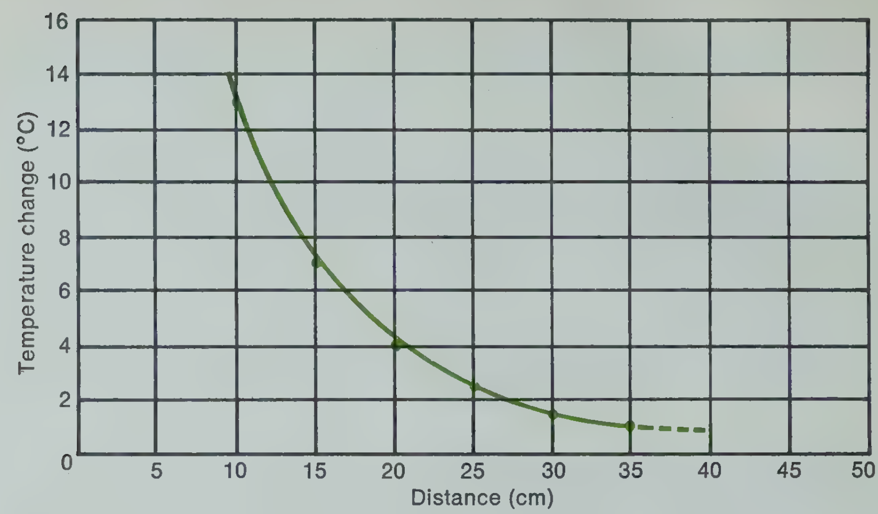
2-9. The greatest temperature change would be produced by the bulb with the highest watt number.

SELF-EVALUATION 3

3-1. a. Your chart should be completed as shown below.

Distance (cm)	Initial temperature °C	Final temperature °C	Temperature change °C
10	25.4	38.4	13.0
15	25.0	32.0	7.0
20	25.2	29.2	4.0
25	25.0	27.5	2.5
30	24.9	26.5	1.6
35	25.1	26.1	1.0

b. Your graph should look like the one shown below.

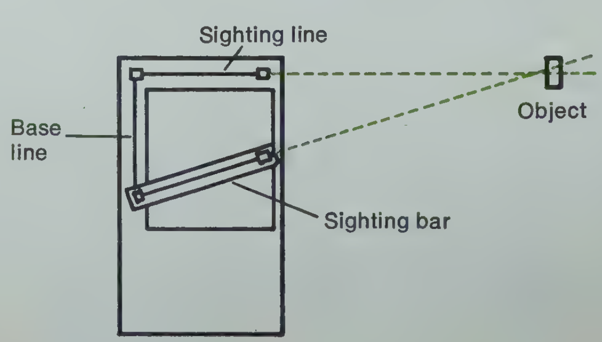


c. Your predicted value should be about 0.8 °C. You can extend the curve on the graph by a dashed line, as shown.

3-2. You may not have been sure of the energy change. You should expect it to be much less at 40 cm than at 20 cm. Actually, the temperature change produced at 40 cm is about $^1/_4$ of what it was at 20 cm. Doubling the distance to the light source *decreases* its effect on the sun-energy measurer by 4 times. You'll learn more about this relationship later.

SELF-EVALUATION 4

4-1. a. You should have labeled your diagram as indicated below.



b. Move the sighting bar away from the base line. If you had difficulty with this question, get a range finder from the supply area and try it out.

4-2. a. The markings on the scale get closer together as the distance measured increases.

b. Here was your chance to be a real inventor. Two of the ideas you may have suggested are (1) make the base line longer; (2) make the sighting bar longer.

4-3. The sighting angle decreases as the distance to the object increases. See Activity 4-3 and the questions that follow it.

4-4. You could have listed many different factors. The main ones are (1) the length of the base line; (2) the smallest angle that you can measure. You may also have mentioned such factors as difficulty in keeping the sighting line pointing at the object while moving the sighting bar, and problems in lining up the same part of the sighting bar with the object each time.

4-5. 3.75 metres. You should be pretty good at measuring distances with your range finder by now. If you are still having difficulties, you may want to discuss this with your teacher.

4-6. b. The line XY represents the base line. Astronomers make sightings from observatories many miles apart to increase the size of their base line. This helps them measure the distance to a distant object. However, in some cases (such as measuring the distance to the sun or to a star), astronomers find that the angle that is to be measured is so small that even using the diameter of the earth as a base line is not enough. (See pages 38 and 39 in your test.) Now if we made one observation in January and another one in July . . . Hmm.

4-7. You cannot get a large enough base line. The sighting angle is too small to measure because the base line is limited. However, it could be measured if the base line could be extended much farther.

5-1. Fact **c** is incorrect. Venus is closer to the sun. See Table 5-1 in your text.

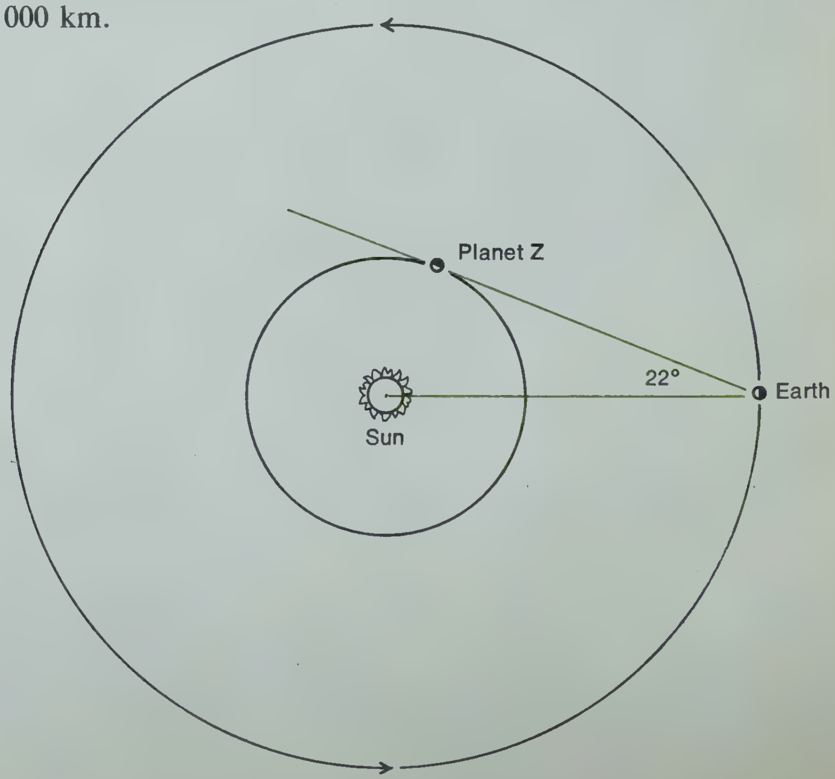
5-2. The students may have difficulty with 338°. They have not been called upon to measure an angle greater than 180° previously. You may have to show them either of two methods:
(1) Extend one side of the angle through the vertex to make a straight angle; measure the angle between this extension and the other side of the angle (158°); add this measurement to 180°.
(2) Measure the acute angle (the part without the curved line, 22°) with the protractor; subtract this measurement from 360°.

5-2. Angle A = 35°, Angle B = 121°, Angle C = 90°, Angle D = 338°. If you measured all four angles correctly, you are doing very well. If you are having difficulty measuring angles, you should do **Resource 9**, "Measuring Angles."

5-3. a. 8 centimetres;
b. 16 km. If you look at the scale drawing, you will notice that it says that 1 cm equals 2 km. If Union Park is 8 cm from Christmas and each centimetre equals 2 km, then Union Park is 16 km from Christmas. If you are having problems with scale diagrams, you should do **Resource 7**, "Scale Reading."

5-4. The greatest possible EX–ES angle for Planet X in this diagram is 45°. If your answer is not within one to two degrees of the answer given, you should check with your teacher or review Activity 5-5 in your text (page 50).

5-5. a, b, c. Your diagram should look like the one shown below.
d, e. The distance you should have measured between the earth and the sun is 64 mm, so that on your scale 1 mm = 2 330 000 km.
f. Planet Z should be about 24 mm from the sun. This is equal to 56 000 000 km.



g. The smallest distance between the earth and Planet Z is 40 mm. This is equal to 83 000 000 km. If you got all parts of this question correct, you did very well. If you had some difficulties, you may want to review pages 52 and 53 in your test.

Table 5-5

		Scale Drawing (mm)	Actual Distance (km)
1	Distance from Planet Z to the sun	24	56 000 000
2	Distance from the earth to the sun	64	149 000 000
3	Smallest distance between the earth and Planet Z	40	83 000 000

SELF-EVALUATION 6

6-1. The relationship can be stated as a simple ratio or proportion. (See page 63 in your text.)

$$\frac{\text{Distance across the object}}{\text{Distance across the image}} = \frac{\text{Distance from object to the pinhole}}{\text{Distance from image to the pinhole}}$$

6-2. In this experiment you determined the size of the image on the screen produced by a source placed at three different distances from the pinhole. You kept the pinhole-screen distance constant (42 cm). The size of the image produced by the source when at

Point A = 2.0 cm across.
Point B = 1.5 cm across.
Point C = 1.0 cm across.

6-3. The relationship you need for this problem is as follows:

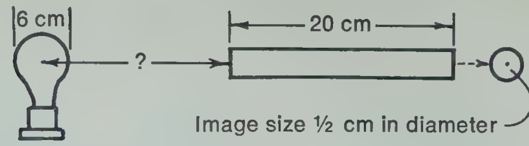
$$\text{Distance across object} = \frac{\text{Distance from object to pinhole}}{\text{Distance from pinhole to screen}} \times \text{Distance across image}$$

Substituting the student's data into this relationship, we get the following:

$$\text{Distance across moon} = \frac{385\ 000\ \text{km}}{57\ \text{cm}} \times 0.5\ \text{cm} = 3\ 380\ \text{km}$$

If your answer is around 3 380 km, you did well. If you had problems, you might want to review pages 65 and 66 in your text.

6-4. a. Your sketch should look something like the one below.



b. Use the relationship given in the answer to 6-3 above.

$$\frac{6 \text{ cm}}{0.5 \text{ cm}} = \frac{\text{Distance from object to pinhole}}{20 \text{ cm}}$$

$$240 \text{ cm} = \text{Distance from object to pinhole}$$

SELF-EVALUATION 7

7-1. a. From sunrise to sunset, the earth makes one half a turn, or 180°.

b. From noon (sun overhead) to sunset, the earth makes one quarter of a turn and this takes 6 hours.

You may realize that in actual fact the day is longer than the night in summer and shorter in winter. The simple model that you used at the beginning of this chapter does not predict or explain this fact. If you had difficulty answering these questions, take another look at Activities 7-1 to 7-10, pages 73 to 77.

7-2. In Activities 7-9 to 7-11, you determined that the sun appears to move through an angle of 15° each hour. Since New York and San Francisco are 3 hours apart, they are 3 × 15°, or 45°, apart. Actually, it is 45° between corresponding points in these time zones. New York City and San Francisco are not corresponding points, and the actual separation between the two is a little over 48°.

7-3. Since it takes 24 hours for the earth to make one rotation on its axis and there is a time difference of 1 hour between time zones, you would cross 24 time zones in a trip around the world. Take another look at Problem Break 7-1 if you had difficulty with this.

7-4. You should disagree with Clint. From what you've seen, it is not possible to tell whether the sun moves around the earth or the earth moves around the sun just by watching the sun's motion. However, it is more logical to think that the earth is moving about the sun.

7-5. This is a real stinker of a question. No doubt you had to think about it for a while. The trick is that the sun is almost directly overhead, so the shadow of the sinker hides the shadow of the string.

7-6. You might have said that the sun would have to move at an unreasonable speed to travel all the way around each day. If the earth is turning on its axis, it would not have to be traveling nearly so fast.

SELF-EVALUATION 8

8-1. You would have to increase the wattage of the source by a factor of 4 in order to keep the same reading. You should review pages 92 and 93 of your text if you had difficulty with this question.

8-2. Your completed table should look like the one shown below. Review pages 92 and 93 if you had problems with this table.

Distances and wattages required to keep the same reading on a sun-energy measurer

Measured distance	Wattage
80 cm	3 200 watts
160 cm	12 800 watts
320 cm	51 200 watts
640 cm	204 800 watts
2 560 cm	3 276 800 watts

8-3. *Power* is defined as "energy transferred per unit of time." A watt is 1 newton•metre per second.

$$\text{Watt} = \frac{1\ \text{N}\bullet\text{m}}{\text{sec}}$$

For more help, see **Excursion 8-1.**

8-4. One hundred cm is 10 times as far as 10 cm. Thus the distance multiplier is 10×. The power multipler equals the distance multiplier times itself.

$$\text{Power multiplier} = 10 \times 10$$

Thus the power multiplier is 100×. See Table 8-1 in the text.

8-5. The spectra show that Star X contains helium; Star Y contains hydrogen and calcium. Star X is also more powerful (releases more energy per unit of time) than Star Y—about 8 times more powerful.

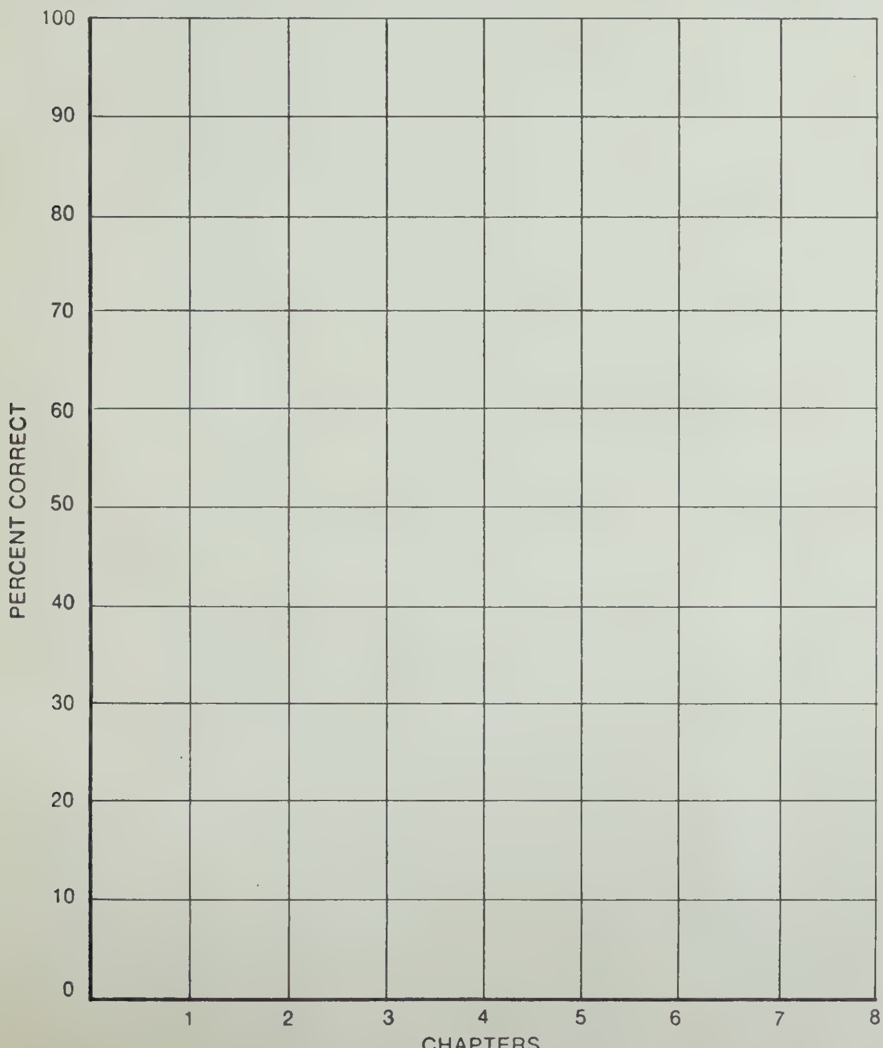
8-6. Your answer should indicate that you would place one of the bulbs at each of the distances, measuring the temperature change each time. You would then use the other bulb at the same distances and make the same measurements. A comparison of the temperature changes would tell you which gives off more energy.

My Progress

Keep track of your progress in the course by plotting the percent correct for each Self-Evaluation as you complete it.

$$\text{Percent correct} = \frac{\text{Number correct}}{\text{Number of questions}} = 100$$

To find how you are doing, draw lines connecting these points. After you've tested yourself on all chapters, you may want to draw a best-fit line. But in the meantime, unless you always get the same percent correct, your graph will look like a series of mountain peaks.



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